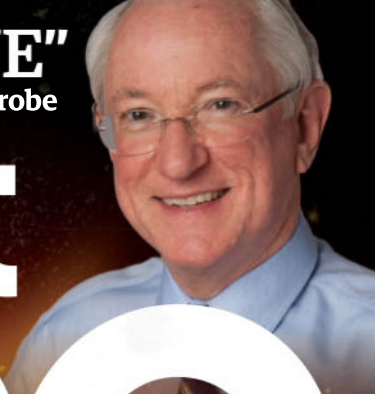


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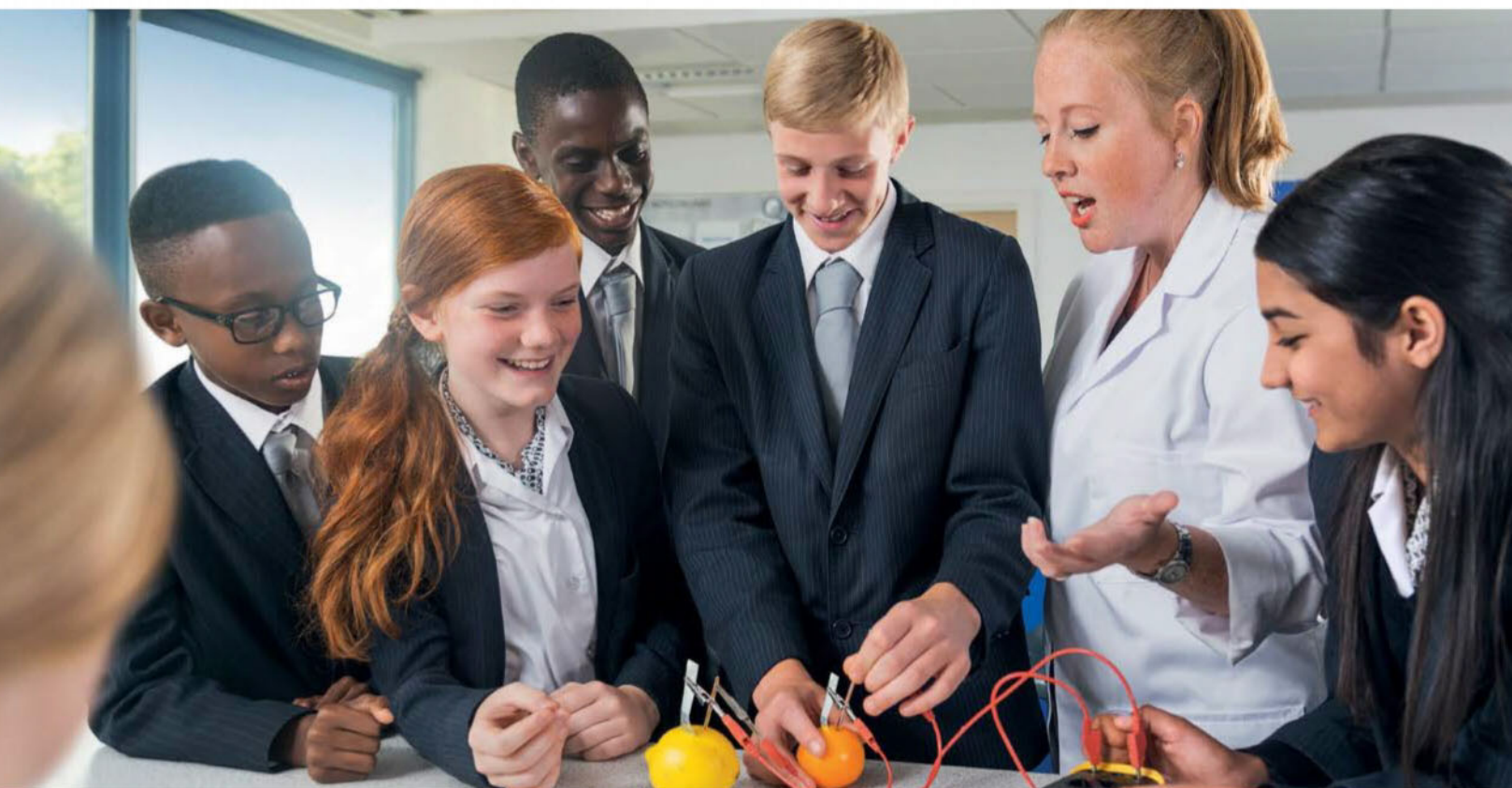
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Discover the wonders of the universe



Space is one of the few subjects where you can throw some utterly crazy hypotheticals out there and within the broader scope of the universe, they'll almost sound like reasonable questions. 'What if the Sun disappeared?' Well, why not? 'What if the Moon

exploded?' Sure, that could happen. 'What if we found alien life?' That's just a matter of time, no? After all, we live in a reality where scientific theory states that massive and incredibly dense objects exist, exerting so much gravity that not even light can escape them. A reality where time slows down, astronauts actually age more slowly in orbit around the Earth and where we can observe celestial objects so distant that their light takes billions of years to reach us - and in all likelihood, they don't even exist any more.

Science is much weirder than any fiction we can conceive of and for any space question you can dream up - however hilarious or off-the-wall you think they are - there's an expert with an answer that will more than match it for sheer jaw-dropping incredulity. You'll find 20 of these space questions and their frequently mind-blowing answers in our cover feature on page 28. We hope you'll enjoy reading it as much as we enjoyed putting it together.

Ben Biggs
Editor

Crew roster

David Crookes



■ Volcanoes are pretty thrilling, so imagine what space volcanoes are like! Read all about it on page 44

Gemma Lavender



■ Gemma is peering into the beautiful universe on both sides of the visible spectrum

Jonny O'Callaghan



■ Taking the helm with our cover feature this month, Jonny is about to blow your mind on 28

Giles Sparrow



■ Giles explains exactly why the Sun (and every other star) is much more than just a hot ball of gas

"They would spend days frantically confirming that the transmission is really coming from ET..."

Dr. Seth Shostak, Centre for SETI Research

SETI's satellites look out toward the night sky, listening for signs of life

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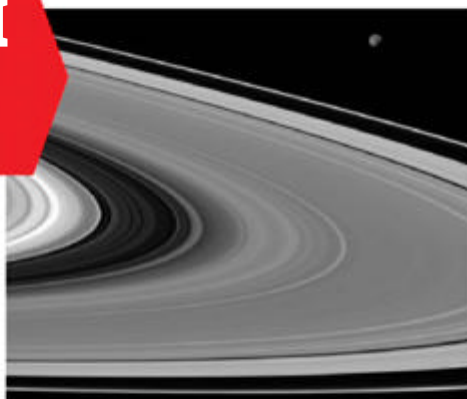
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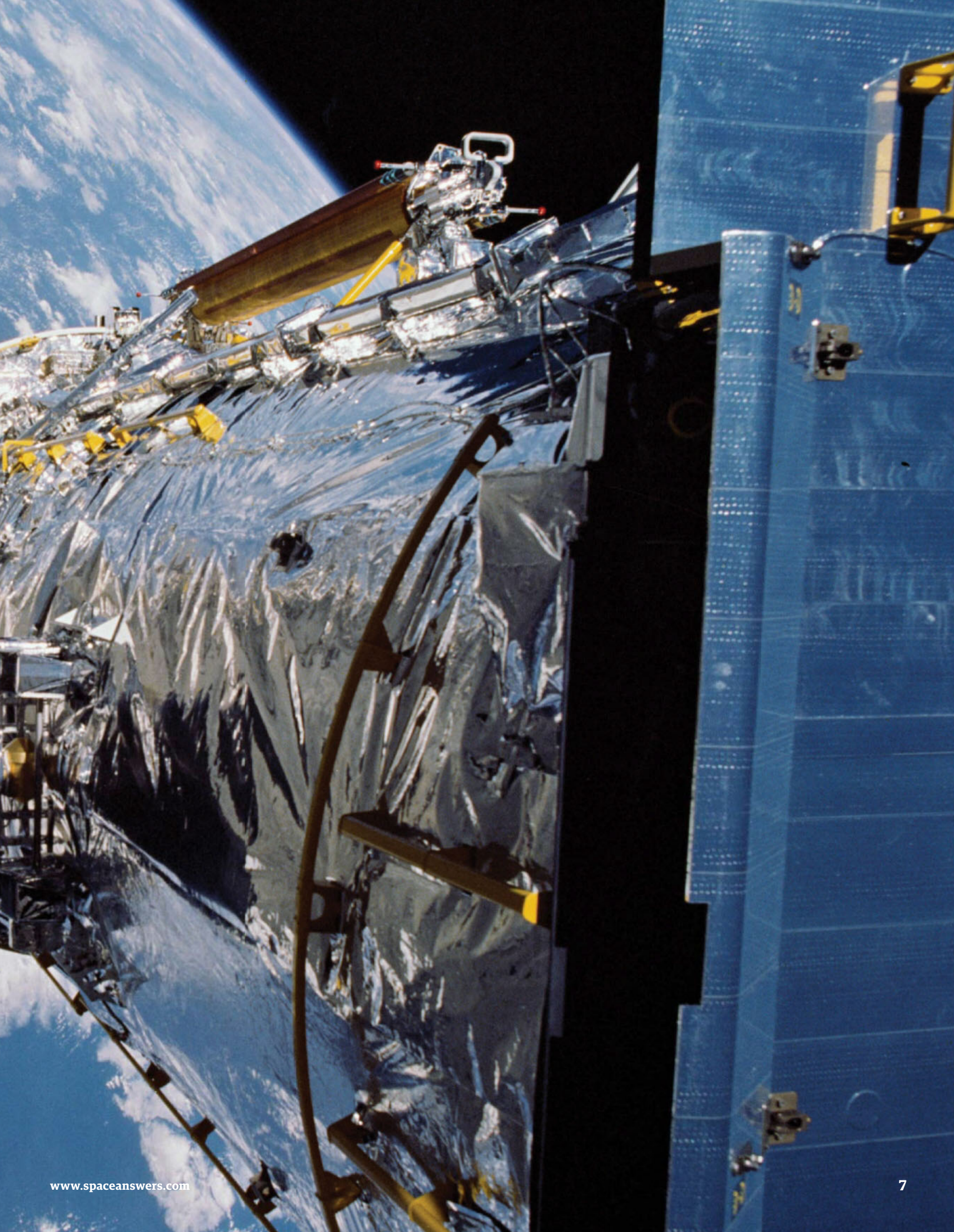
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YOUR FIRST CONTACT WITH THE UNIVERSE

Hubble is deployed

25 years ago on 25 April 1990 the famous Hubble Space Telescope was released into orbit. This image shows the Hubble Space Telescope at an altitude of around 615 kilometres (382 miles) above the Earth. Here it's being held in place outside Discovery's cargo bay, while the astronaut crew in the cabin extend the telescope's solar array panels and antennae. Incidentally, the pilot for that mission was Charles F Bolden, Jr – NASA's current administrator.

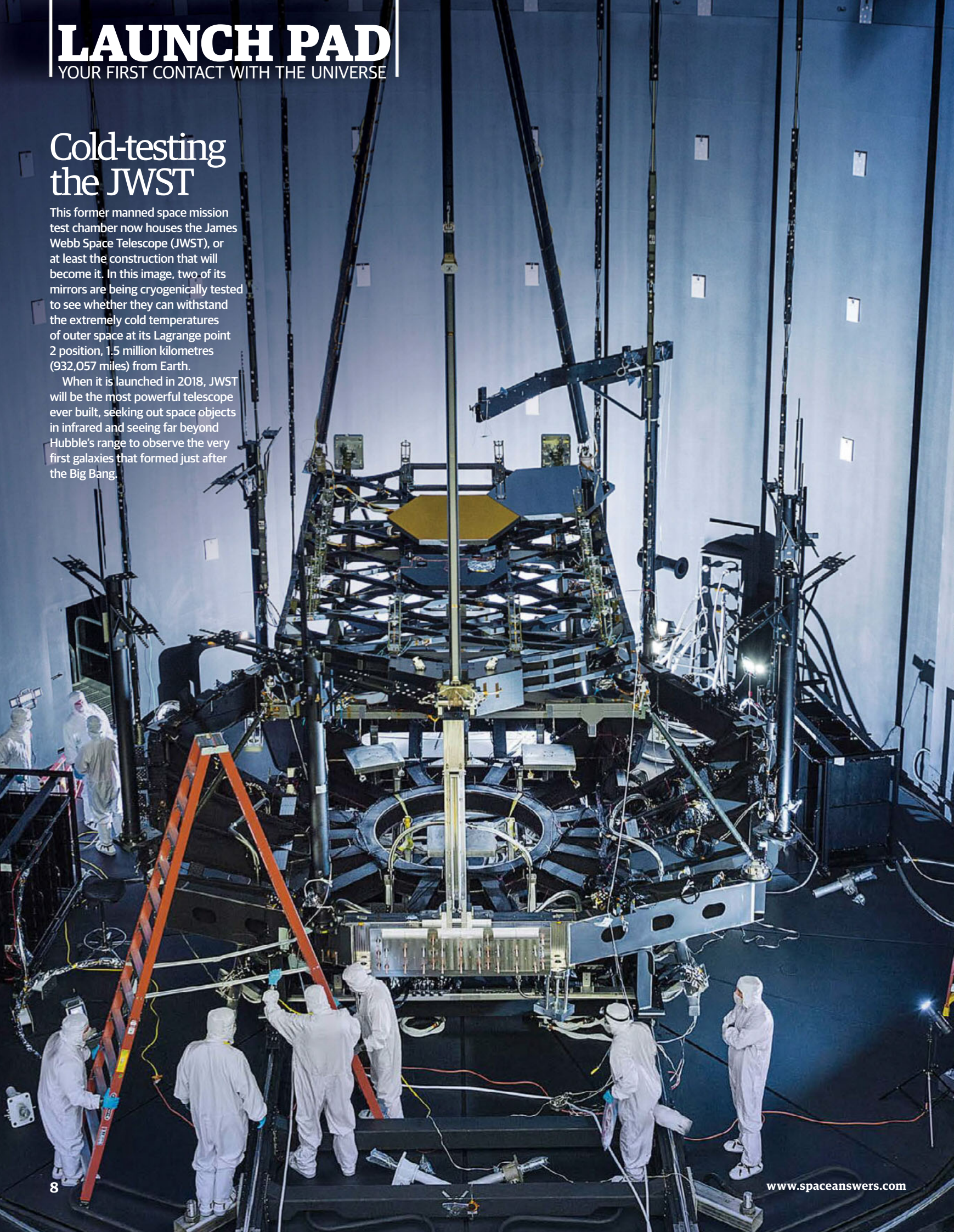


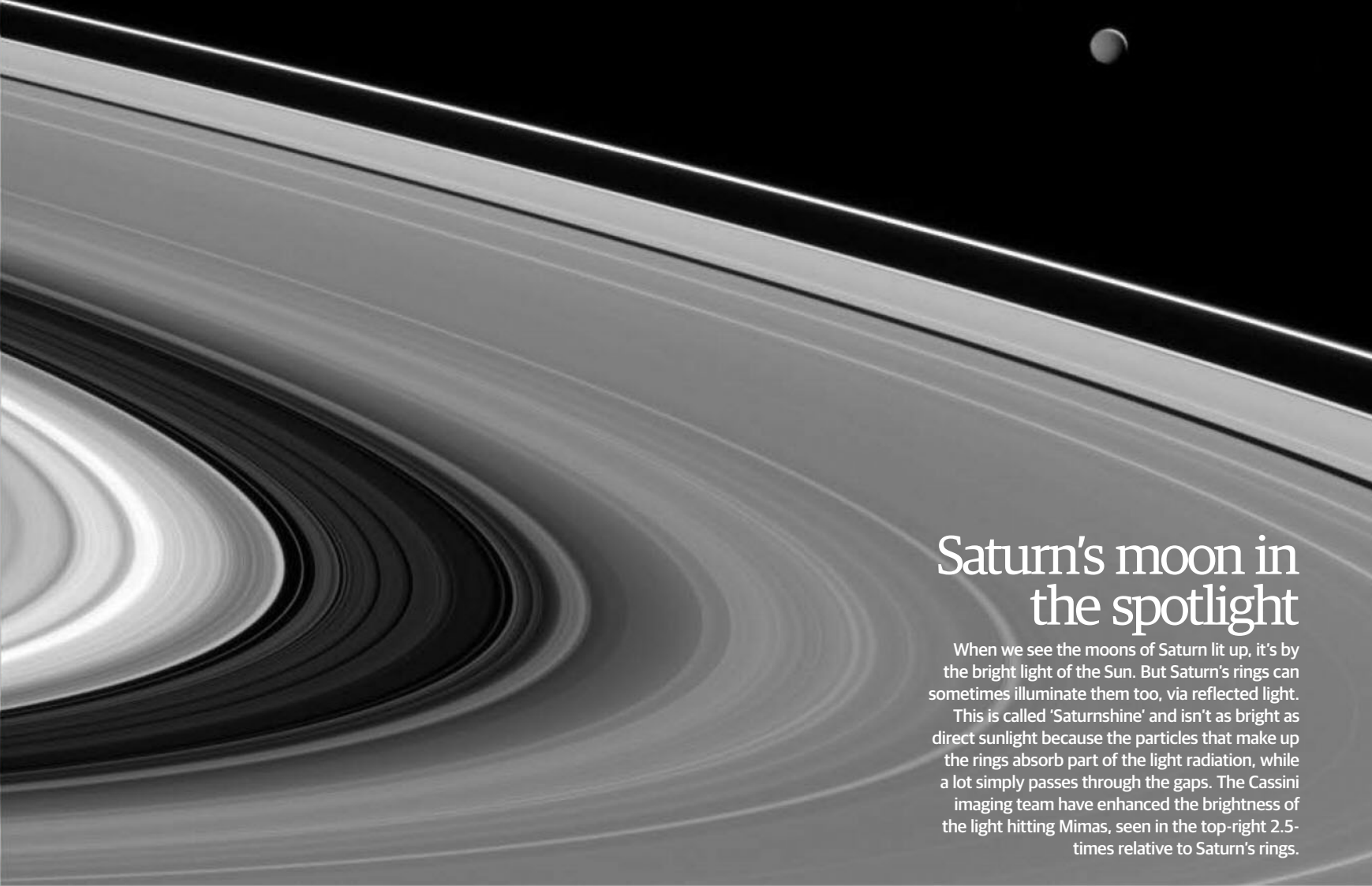


Cold-testing the JWST

This former manned space mission test chamber now houses the James Webb Space Telescope (JWST), or at least the construction that will become it. In this image, two of its mirrors are being cryogenically tested to see whether they can withstand the extremely cold temperatures of outer space at its Lagrange point 2 position, 1.5 million kilometres (932,057 miles) from Earth.

When it is launched in 2018, JWST will be the most powerful telescope ever built, seeking out space objects in infrared and seeing far beyond Hubble's range to observe the very first galaxies that formed just after the Big Bang.





Saturn's moon in the spotlight

When we see the moons of Saturn lit up, it's by the bright light of the Sun. But Saturn's rings can sometimes illuminate them too, via reflected light.

This is called 'Saturnshine' and isn't as bright as direct sunlight because the particles that make up the rings absorb part of the light radiation, while a lot simply passes through the gaps. The Cassini imaging team have enhanced the brightness of the light hitting Mimas, seen in the top-right 2.5-times relative to Saturn's rings.



Planetary destruction

Scientists have found evidence for the destruction of a planet by a white dwarf star at the edge of an ancient star cluster. When the Chandra X-Ray telescope took this image of globular cluster 6388, a strong source of X-ray emission was thought to be gas falling onto a large black hole near its centre, but Chandra pinpointed the source somewhere off to one side. A sudden dip in the X-ray brightness suggested that they might be from tidal disruption, or in other words, a white dwarf star tearing a planet apart with its immensely powerful gravitational forces.

Cloud city La Silla

For those of you who are *Star Wars* fans, this could easily be mistaken for a still from *Episode VII - The Force Awakens*. In actual fact it is a photo of the European Southern Observatory's La Silla Observatory, responsible for many of the stunning space images that you can see between the pages of *All About Space*. La Silla can be found in Chile's Atacama Desert, which is normally very dry and dusty. Although it gets cold here at high altitudes, temperatures rarely drop below freezing, but the lower atmospheric humidity means snow can form at higher temperatures.





Polar ice cap revealed in close up images of Pluto's surface

The dwarf planet's surface features are becoming more apparent as New Horizons moves closer

The New Horizons mission has spied details on the surface of Pluto for the first time as it hurtles toward a close encounter with the dwarf planet on 14 July. The NASA spacecraft saw light and dark markings, as well as a possible polar ice cap.

"As we approach the Pluto system we are starting to see intriguing features such as a bright region near Pluto's visible pole, starting the great scientific adventure to understand this enigmatic celestial object," says John Grunsfeld, a former shuttle astronaut who is now the associate administrator of NASA's Science Mission Directorate.

New Horizons is able to see Pluto's pole because the dwarf planet is tipped on its side, revealing its pole to the spacecraft's on board camera. The pole appears bright, possibly because of nitrogen ice that has fallen from its thin atmosphere and on to the mysterious surface.

"After travelling more than nine years through space, it's stunning to see Pluto, literally a dot of light as seen from Earth, becoming a real place before our eyes," says Alan Stern, who is the principal investigator on New Horizons at the Southwest Research Institute.

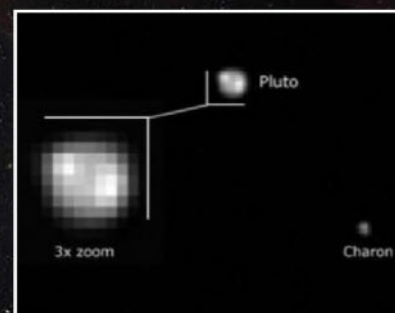
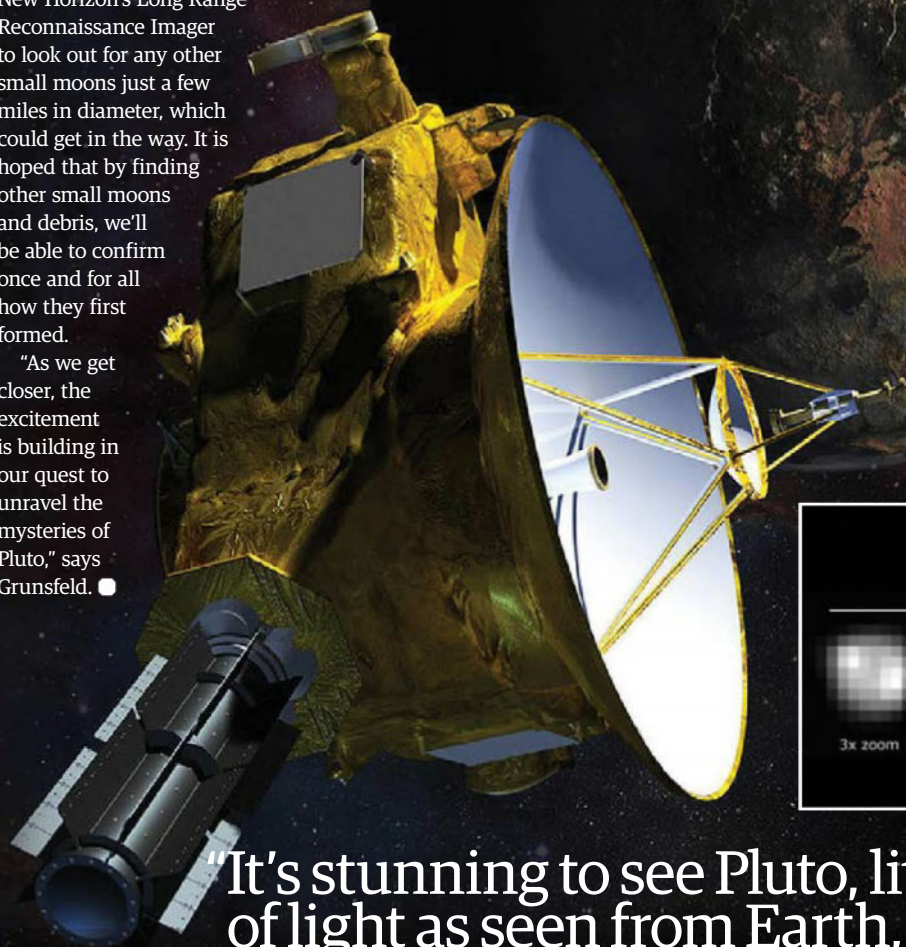
The spacecraft has also been able to take images of Pluto's largest moon, Charon, which is fairly similar in size to the dwarf planet. Pluto's remaining four moons, called Nix, Hydra, Kerberos and Styx, are each less than 80 kilometres (50 miles) across and are yet to be investigated by New Horizons. Since it is thought that these moons are the fragments of an ancient impact that later combined to form Charon, the New Horizons team are keeping their eyes peeled for leftover wandering chunks of space rock that could bombard the

spacecraft. New Horizons is racing through space at a speed of around 48,280 kilometres (30,000 miles) per hour, so if there is a collision with even the smallest of dust-sized particles, the spacecraft will be completely destroyed.

However, the team have put the odds of that happening as one in 10,000, although they are using New Horizons' Long Range Reconnaissance Imager to look out for any other small moons just a few miles in diameter, which could get in the way. It is hoped that by finding other small moons and debris, we'll be able to confirm once and for all how they first formed.

"As we get closer, the excitement is building in our quest to unravel the mysteries of Pluto," says Grunsfeld. ●

Pluto could have a polar ice cap according to these new images from NASA's New Horizons



"It's stunning to see Pluto, literally a dot of light as seen from Earth, becoming a real place before our eyes"

Dr Alan Stern, Southwest Research Institute

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"Dark matter may not be completely 'dark' after all"

Our original perception of dark matter could be wrong thanks to the result of a galactic crash

It appears that dark matter, the mysterious material that makes up 85 per cent of the universe's mass, is not as dark as previously thought.

Dark matter, which stops galaxies like the Milky Way flying apart, is referred to as dark because it's thought to only ever interact with gravity and because it's not willing to interact with anything but, it makes itself invisible. However, training the Hubble Space Telescope on the galactic collision, which occurred at the centre of the galaxy cluster, Abell 3827, some 1.3 billion light years away has potentially blown this theory out of the water. It seems that a clump of the dark material has responded to some force that has caused it to lag behind the galaxy melee it surrounds by around 5,000 light years - a distance that would take NASA's Voyager spacecraft 90 million years to travel.

"We used to think that dark matter sits around, minding its own

business," says astronomer Dr Richard Massey from Durham University. "But if it slowed down during this collision, this could be the first dynamical evidence that dark matter notices the world around it. Dark matter may not be completely 'dark' after all."

Massey and his international team of astronomers were able to see the lagging clump of dark matter thanks to the effect of gravitational lensing, where the dark matter's mass is seen to distort the light of the galaxy behind it.

It's going to take more observations of other galaxies along with computer simulations to chronicle the effects of galaxy collisions before the team can pass their observations as fact, but Massey is optimistic.

"We are finally homing in on dark matter from above and below - squeezing our knowledge from two directions," adds Massey. "Dark matter, we're coming for you." ●

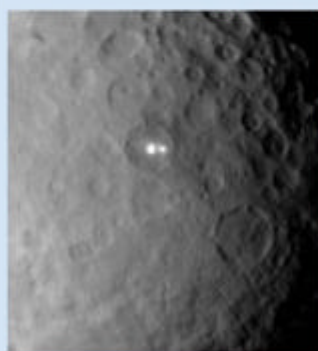


Has the galactic smash-up at the centre of this galaxy cluster changed our theories about dark matter?

"This could be the first evidence that dark matter notices the world around it"

Dr Richard Massey, Durham University

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Astronomers are offering the public the chance to explain the strange bright spots on Ceres

Ceres' mysterious bright spots return to view

Two mysterious bright spots discovered by the Dawn mission on the dwarf planet Ceres have come back into the spacecraft's view as scientists struggle to understand what these bizarre features are.

Dawn arrived at Ceres in March, having spotted the bright regions on its approach a few months earlier. However, Dawn then went into orbit around Ceres' nighttime hemisphere and was unable to see anything on the surface until early April. Scientists are puzzled as to what the bright spot could be and have even set up a website where you can cast your opinion about what they are. Are they some sort of ice volcano? A bright salt deposit or geyser? Exposed ice? A surprisingly bright patch of rock or something else?

Dawn is now getting closer to the surface of Ceres to start mapping it with high-resolution photographs. "The bright spots continue to fascinate the science team, but we will have to wait until we get closer and are able to resolve them before we can determine their source," says Christopher Russell, the mission's principle investigator at the University of California. ●



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No alien life in 100,000 galaxies

There are no signs of distant alien civilisations having totally colonised their galaxy, reports scientists from Penn State University, who searched an impressive 100,000 galaxies using NASA's WISE telescope.

Water vapour erupts in curtains on Saturn's moon

The geysers of water vapour erupting from Saturn's moon Enceladus may not be single plumes at all, but curtains of ice and water along the cracks that line its southern hemisphere.

Astronomers set new galaxy distance record

A galaxy has set a new distance record after astronomers using the 10m (32.8ft) Keck telescope in Hawaii measured it to be over 13 billion years old. The galaxy is so young that astronomers see it only 100 million years after it formed.

Asteroid mining mission to launch this summer

The asteroid mining company, Planetary Resources, is planning on launching its first test flights later this year. The Arkyd-3R probe is a prototype that will survey near-Earth asteroids.



Compact galaxies were thrown out of the cluster thanks to an interaction with neighbouring galaxies

Astronomers uncover unexpected runaway galaxies

We've seen stars and even entire star clusters flying through the universe, but now astronomers have spotted 11 galaxies on the run, some of which are now wandering the void of intergalactic space.

However, it wasn't a decision the galaxies made entirely by themselves. According to astronomer Igor Chilingarian, these galaxies were thrown out of the galaxy cluster they once called home by members of their galactic family at a breakneck speeds of up to 3,000 kilometres (1,864 miles) per second. "These galaxies are facing a lonely future, exiled from the galaxy clusters they used to live in," he says.

Chilingarian dubs these structures as runaway galaxies because they're moving so fast that they've managed to break free of the gravity that's been holding them at home for so long. But it wasn't what he or his fellow researcher, Ivan Zolotukhin, were expecting, since they had originally set out to find members of a class of galaxies called compact ellipticals (blobs of stars that are bigger than a star cluster), mere dwarfs in comparison to our 100,000 light year-diameter Milky Way galaxy.

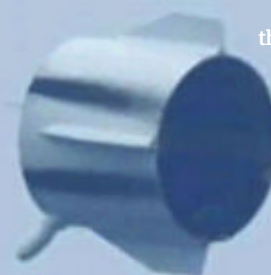
"We recognised we could use the power of the archives to potentially unearth something interesting and we did," adds Chilingarian. ■

Musk reports "great outcome" on test of SpaceX astronaut bailout system

A critical system designed to save astronauts in a launch emergency is successfully completed

SpaceX have moved a step closer to launching people into space after performing a dramatic test of their rocket escape system, which will propel astronauts to safety should their rocket explode beneath them after take-off.

The company, run by billionaire Elon Musk, is working on a crewed version of their Dragon space capsule that has been ferrying cargo supplies to the International Space Station. On 6 May, SpaceX tested the Dragon's abort system by blasting it off the launch pad at Cape Canaveral, Florida. Using its SuperDraco launch abort engines, it reached a height of 1,524 metres (5,000 feet) before the crewed compartment, which was empty at the



The Dragon craft was photographed separating from the engine during a test flight

time (except for one human-shaped dummy), detached and floated back to the ocean under three parachutes.

"It was a great outcome," Musk says. "The important thing is that if there had been people on board, they would have been in great shape."

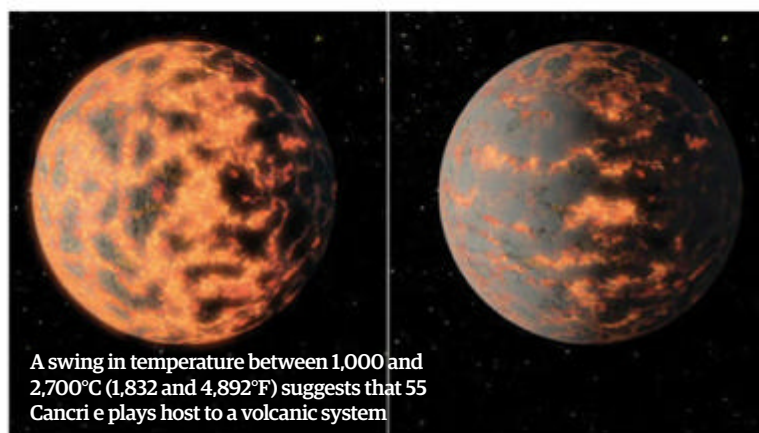
The Dragon crewed capsule is being developed for 2017, when United States astronauts will begin using it to reach the International Space Station, instead of having to buy rides on Russian Soyuz spacecraft, which already use a similar abort system. ■

Exoplanet's intense heat points to existence of alien volcano

Temperatures fluctuating wildly on a nearby exoplanet could be the result of volcanic activity

The first ever detections made of the wildly changing temperature of a planet outside our Solar System could be down to extraterrestrial volcanoes spewing intense heat into its atmosphere.

The super-Earth in question, known as 55 Cancri e, is twice the size of our planet and eight-times its mass, orbiting a Sun-like star. Keeping an eye on the planet, the Spitzer Space Telescope has seen a threefold change in its temperature over two years, seeing the planet's forever Sun-facing side being blasted to temperatures that swing between 1,000 and 2,700



A swing in temperature between 1,000 and 2,700°C (1,832 and 4,892°F) suggests that 55 Cancri e plays host to a volcanic system

degrees Celsius (1,832 and 4,892 degrees Fahrenheit).

"We saw a 300 per cent change in temperature, which is the first time we've seen such a huge level of variability in an exoplanet," says Cambridge University's Dr Brice-Olivier Demory. "While we can't be entirely sure, we think that a likely explanation for this variability is large-scale surface activity, possibly volcanism, on the

surface that is spewing out massive volumes of gas and dust"

The observation has thrown doubt on the identity of the planet. "When we first identified this planet, the measurements supported a carbon-rich model," says Nikku Madhusudhan. "Now we're finding those measurements are changing in time. The planet could be carbon rich, but now we're not so sure." ■

Hubble - 25 Years of Space Exploration



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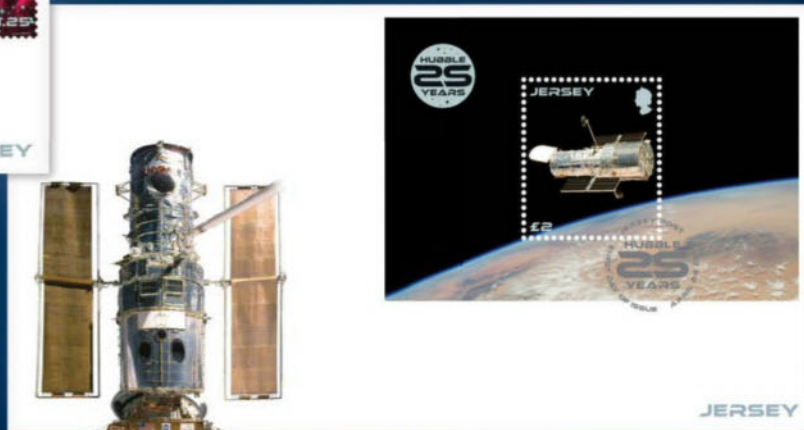
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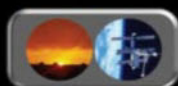
Celebrating 25 years since its launch, eight stamps feature spectacular images from the Hubble Space Telescope. The Miniature Sheet features the Hubble in its final release over Earth.

Images courtesy of www.hubblesite.org NASA and STScI

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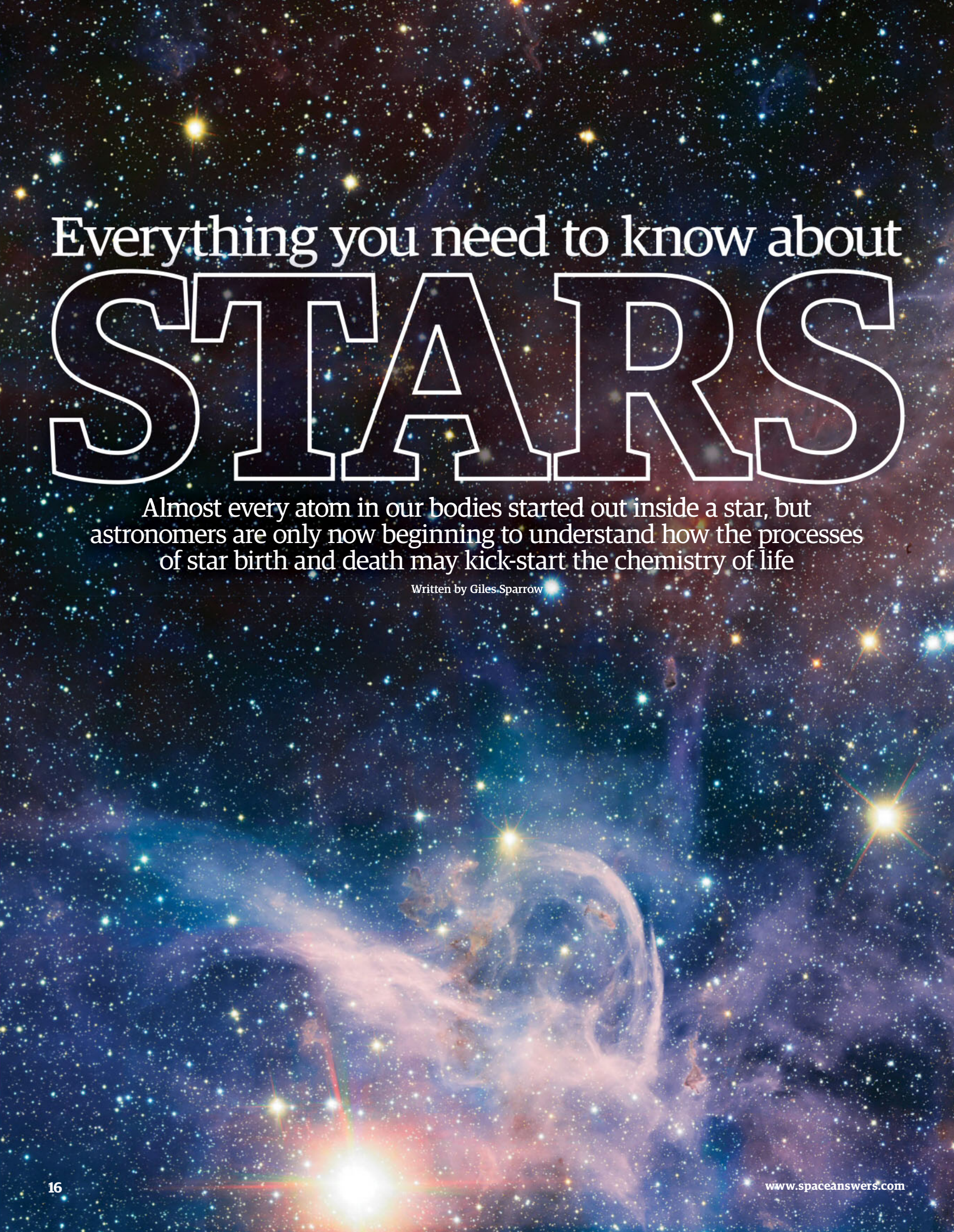
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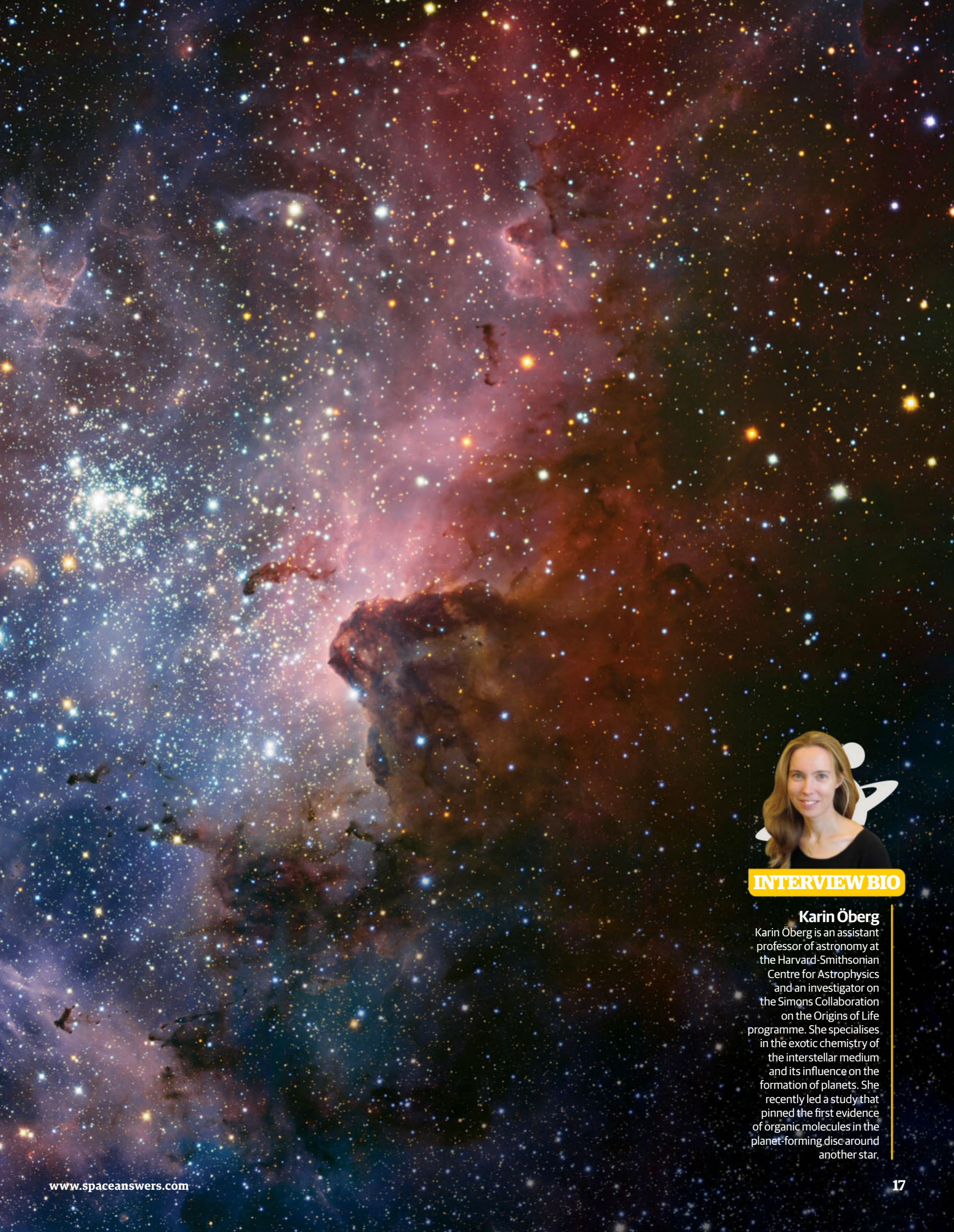
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Everything you need to know about STARS

Almost every atom in our bodies started out inside a star, but astronomers are only now beginning to understand how the processes of star birth and death may kick-start the chemistry of life

Written by Giles Sparrow



INTERVIEW BIO

Karin Öberg

Karin Öberg is an assistant professor of astronomy at the Harvard-Smithsonian Centre for Astrophysics and an investigator on the Simons Collaboration on the Origins of Life programme. She specialises in the exotic chemistry of the interstellar medium and its influence on the formation of planets. She recently led a study that pinned the first evidence of organic molecules in the planet-forming disc around another star.

Stars: all you need to know

Astronomers have understood for decades that we owe our existence on planet Earth to the work of previous stellar generations. Over billions of years of cosmic history, the nuclear furnaces in the hearts of stars have been responsible for producing the heavy elements that rocky planets like our own are made of. As the great astronomer Carl Sagan once said, "we are made of star stuff."

The idea that most of the atoms in or bodies were born in ancient stars is an awe-inspiring thought on its own, but recently astronomers have begun to realise just how much further the various processes of star birth, ageing and death can advance the chemistry of life itself. It's increasingly clear that the complex biomolecular engineering that underlies life did not all need to be created from scratch on the primordial Earth, but was instead kick-started by the presence of carbon-based chemicals in the raw material of our Solar System. What scientists are trying to uncover now is just how far this cosmic chemistry set can take the process on its own and what implications that has for the chances of life elsewhere in the universe.

The universe, created by the Big Bang some 13.8 billion years ago, was composed almost entirely of the two lightest elements - hydrogen and helium, with hydrogen atoms making up about three-quarters of the universe's mass and the tiniest trace of the next heaviest element, lithium. Yet the

universe around us today is very different, it has been enriched by heavier elements such as carbon, oxygen, sulphur, iron, lead and uranium. Together these elements still comprise just two per cent of all the matter in the universe, but they are hugely significant to us because it is these heavier elements that concentrate together to form planets like Earth and living beings like ourselves.

So how did the universe become enriched with these heavier elements? Astronomer Karin Öberg of the Harvard-Smithsonian Centre for Astrophysics (CfA) points to the answer: "They come from dying stars, stellar winds and supernova explosions releasing these heavy elements that have been produced inside the stars. And these heavy elements are the starting point of any interesting chemistry - without them we'd only have hydrogen and helium."

Öberg's research focuses on the interstellar chemistry needed to get more complex molecules, but it builds on ideas of stellar nucleosynthesis, which was developed by astronomers throughout the 20th century. All stars are initially dominated by hydrogen and helium, but the intense pressures

and temperatures at their cores allow nuclear fusion reactions to take place, fusing lightweight atomic nuclei together to create heavier ones that release more energy.

Stars spend the majority of their lives fusing hydrogen into helium, which is a long and stable middle-age known as their main sequence lifetime. For stars like the Sun, this period may last for billions of years and it's the prime opportunity for life to take hold on any planets orbiting it at a suitable distance. But as a star nears the end of its life and begins to exhaust the supplies of hydrogen in its core, it must find new types of fusion in order to keep shining. The solution is to fuse helium nuclei with each other or the remaining hydrogen, building heavier elements including carbon, oxygen, nitrogen, neon and sulphur. As the star's internal energy balance changes, it actually becomes more luminous and swells in size, while its surface cools and becomes an unstable red giant.

For stars like our Sun, this is as far as the nuclear fusion process can go, but in those with more than eight-times the solar mass, the process can continue

"These heavy elements are the starting point of any interesting chemistry" Karin Öberg

Early stars could have weighed more than 1,000 Suns



The first stars

The spread of heavy elements throughout the universe has had a substantial influence on the prospects for life and the nature of stars themselves. The incorporation of heavier elements, known generally as metals, accelerates the nuclear fusion process, making stars burn faster and brighter, shortening their lifetime. Today's universe contains a mix of metal-rich stars that formed in the past few billion years, known as Population I stars. Fainter red and yellow stars with fewer metals fall under the category of Population II. However, astronomers think that the first stars in the universe were a hypothetical Population III, made of pure hydrogen and helium. These stars could have grown larger than anything in the universe today, perhaps weighing as much as 1,000 Suns and their deaths would have scattered the first heavy elements across the universe.

Star deaths scatter heavy elements across the universe



■ A mature Solar System

During the star's middle age, it shines by fusing the hydrogen in its core into helium. This stable phase may last for billions of years in a star like the Sun, or just a few million for more massive stars. It is now that planets orbiting longer-lived stars have the potential to give rise to life.

■ Death and dispersal

As a star begins to exhaust its fuel, it brightens and swells into a red giant or supergiant. This change spells doom for any life on its orbiting planets, but also allows the star to create heavier elements such as carbon, nitrogen and oxygen, which are the raw ingredients of new life. A Sun-like star's final act is to fling its outer layers into the interstellar medium, while its burnt core subsides into a dense white dwarf.

■ Protoplanetary disc

As knots of gas grow hot and dense enough to shine as stars, they are often left surrounded by broad discs of gas and dust. The mix of dust grains, hydrogen and heavier elements creates an ideal environment for efficient chemistry that accelerates the creation of complex molecules. These molecules are incorporated into planets as they form and are dumped on their surfaces by collisions with interplanetary debris.

Birth and death of a star

Discover the life cycle of these explosive entities

■ Starbirth nebula

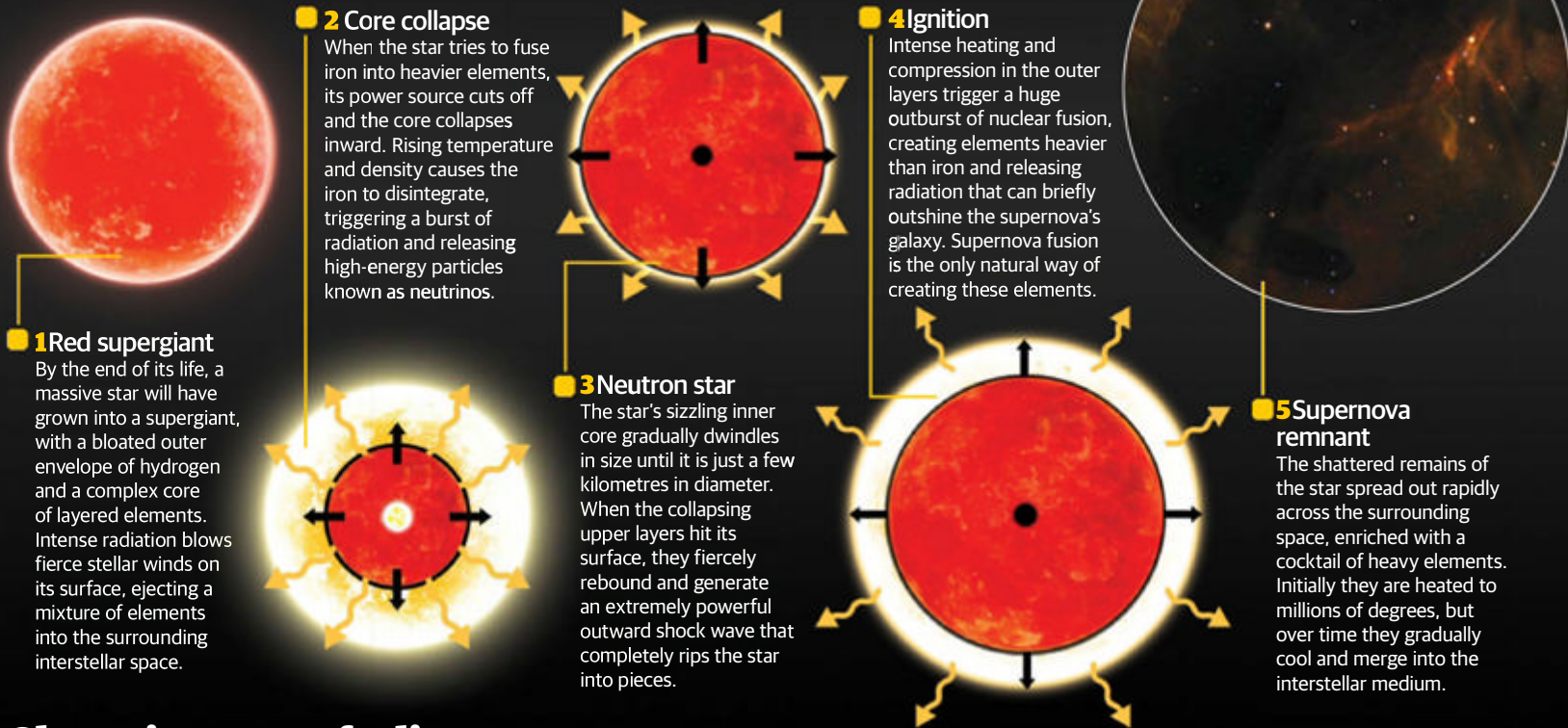
Triggered by a supernova shock wave, gravity from a passing star, or passage through a galaxy's spiral arms, clouds of interstellar gas begin to collapse, becoming dense enough in places for gravity to take over and a runaway process of star formation to begin. Ultraviolet radiation from the young stars energise the hydrogen and cause it to fluoresce, creating a starbirth nebula.

■ Interstellar medium

Huge clouds of gas between the stars are dominated by hydrogen and helium, but are enriched with a small but significant quantity of heavier elements. These clouds form the skeleton of our galaxies and are mostly detectable through their weak radio-wavelength emissions. Dark grains of light-absorbing dust originate within the atmospheres of dying stars and provide a surface on which atoms can come together and bond to form water and simple organic molecules.

5 Stages of a supernova

Massive stars have a different life cycle to their smaller cousins, generating heavier elements throughout and ending their lives in violent supernova explosions



Observing at a safe distance



“Through occasional outbursts, a truly massive star may shed several Sun’s worth of matter, even as it continues to shine”

even as the core’s supply of helium begins to run out. Intense heat and pressure allows nuclei of carbon, oxygen and other atoms to fuse with remaining helium nuclei and each other, building increasingly heavy elements, such as neon, sodium, magnesium and silicon. Fusion of silicon builds elements such as argon, titanium and iron.

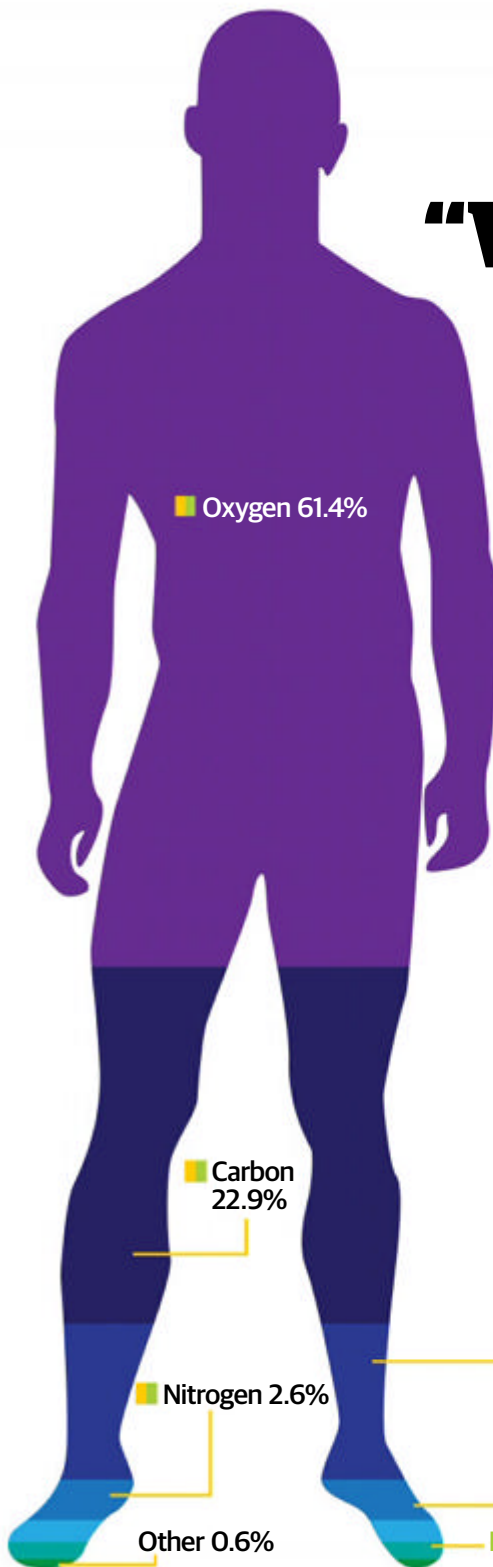
What happens to the heavy elements after that? In Sun-like stars, the vast majority remain trapped inside the star itself and as helium fusion starts to falter, its outer layers become unstable and are ejected into space as a planetary nebula – a short-lived but beautiful cosmic ring. The core, containing much of the star’s mass and most of its heavy elements, remains behind as a white dwarf, which is an intensely hot and dense ball of matter about the size of Earth, dominated by carbon and oxygen.

In contrast, stellar heavyweights are more generous with their bounty. Toward the end of their lives, they too swell up to become unstable, highly luminous supergiant stars. The intensity of their radiation blows significant amounts of metal-enriched material out of their atmospheres into the surrounding space as a powerful stellar wind. In this way and through occasional unpredictable outbursts, a truly massive star may shed several Sun’s worth of matter, even as it continues to shine.

Once it has generated a small, iron-rich inner core, the star may then attempt to fuse iron in order to keep shining, but this can have unexpected and spectacular results as iron is the first element that fusion absorbs, rather than releases. The star’s power supply is abruptly cut off, along with the tremendous outward pressure that previously supported its upper

"We are made of star stuff"

The periodic table is the standard way of illustrating the 118 known chemical elements. They are ordered by their internal compositions and structures, but in general, elements get heavier and more complex from left to right



What are stars made of?

What are stars made of?																	He	
H																	B	
Li	Be												B	C	N	O	F	Ne
C	C												C	S L	S L	S L	S L	S L
Na	Mg												Al	Si	P	S	Cl	Ar
L	L												\$ L	\$ L	L	S L	L	L
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	
L	L	L	\$ L	\$ L	L	L	\$ L	\$	\$	\$	\$	\$	\$	L	\$	\$	\$	
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	
\$	L	L	L	L	\$ L	L	\$ L	\$	\$ L	\$ L	\$ L	\$ L	\$ L	\$	\$	\$	\$	
Cs	Ba		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	
\$	L		\$ L	\$ L	\$ L	\$	\$	\$	\$	\$	\$ L	\$ L	\$	\$	\$	\$	\$	
Fr	Ra																	
\$	\$																	
		La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu		
		L	L	\$ L	\$ L	\$ L	\$ L	\$	\$	\$	\$	\$	\$	\$	\$ L	\$		
		Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr		
		\$	\$	\$	\$	\$	\$	M	M	M	M	M	M	M	M	M		

L Large stars

Massive stars continue the nuclear fusion process longer than Sun-like ones, producing elements up to and including iron. Non-fusion processes can even generate some elements beyond iron, such as copper.

B Big Bang

The two lightest elements in the universe, hydrogen and helium, were created in vast quantities by the Big Bang some 13.8 billion years ago.

S Small stars

The later stages in the life of stars like our Sun make a significant contribution to the universe's overall amount of carbon, nitrogen, oxygen, neon and sulphur.

\$ Supernovae

The heaviest natural elements in the universe are created during the uncontrolled burst of nuclear fusion that marks a supernova explosion.

C Cosmic rays

Lithium, beryllium and boron are light elements that are not manufactured in stars or supernovae. Instead they owe their origins to the break-up of carbon and oxygen atoms in space when they are struck by high-energy particles from stars, called cosmic rays.

M Man Made

"It turns out that some of the most efficient chemical factories are tiny microscopic grains that exist everywhere" **Karin Öberg**

layers. The result is a sudden implosion of the core, rebounding in a shock wave that tears the star apart. This is commonly known as a Type II supernova explosion. As the shock rips through the star's upper layers, it produces temperatures and pressures far higher than those reached in the core, igniting a firestorm of nuclear fusion that rapidly builds nuclei far heavier than iron. Elements such as lead, gold and uranium are scattered across space in a rapidly expanding supernova remnant.

High-mass stars that turn into supernovae are vastly outnumbered by more sedate stars like our Sun, but their accelerated life cycles allow them to make a far greater contribution to the mix of interstellar materials. In the 13.8 billion years since the universe was born, there has only been time for a couple of generations of Sun-like stars, but perhaps

more than 2,000 generations of high-mass monsters have lived and died in that time. What's more, the presence of heavier elements within stars actually helps to speed up their life cycles in various ways, making them burn brighter and faster. Astronomers can see the effects of this in the form of three distinct stellar populations that fill the universe.

So far we've only seen one side of the story, the way in which the raw materials of star formation become enriched with heavy elements. But what about the other side? How and where do these elements build into complex molecules and reach the surface of planets?

Surprisingly, the process seems to start even before star formation. The interstellar medium (vast clouds of cold gas and dust distributed among the stars of our galaxy) might seem like a barren and

uninteresting place, but Karin Öberg argues that it's anything but: "When it comes to chemistry, molecules start forming in the material between stars. It turns out that some of the most efficient chemical factories are tiny microscopic grains that exist everywhere."

Such grains typically have cores rich in carbon or silicate and are thought to form by condensing in the relatively cool outer atmospheres of red giants and supergiants. Studies of the way grains absorb light from their stars suggests that they can include quite complex molecules, including chains and rings of carbon. "These tiny grains are scattered across space by the stellar winds and supernovae," continues Öberg, "Their surfaces are where things like water form and also more complex organic chemicals that we might be interested in."

Stars: all you need to know

So how exactly does this process of molecule building work? "We're most certain about the case of water," admits Öberg. "There, it's simply a matter of an oxygen atom gently landing on it and sitting around there until a hydrogen atom comes along, jumps around and finally finds the oxygen. That has to happen twice to get a water molecule."

The dust acts as a forge for making molecules because both oxygen and hydrogen are weakly attracted to it through so-called 'van der Waals' forces. These are weak attractions created when a molecule contains slight concentrations of electric charge in certain parts. "They're the weakest type of force you can have between molecules," points out Karin, "but you only need small forces because it's very cold, typically about ten degrees Celsius (50 degrees Fahrenheit) above absolute zero. The molecules aren't moving around much, so you don't need a strong force to hold things together."

Intriguingly, the supernovae that scatter heavy elements across space also have a key role to play in the birth of new stellar generations out of the interstellar medium. The passage of their shock waves is thought to be one of several triggers that begin the collapse of gas and dust clouds. Over around 1 million years or more, these clouds slowly coalesce into full-fledged, star-forming nebulae and individual knots develop sufficient gravity to pull in material from their surroundings. This forms hot, dense protostars, often surrounded by a protoplanetary disc that contains the raw ingredients for a brand new Solar System.

A key question is what happens to the various organic chemicals at this point, some of which have low melting points and could potentially be vulnerable to destruction in the fierce environment around a young star. Karin Öberg explains the problem, "We know that these kinds of molecules must have been present in the young Solar System because we see them in comets and they're quite common in the interstellar medium. But until recently we didn't have direct evidence for whether they survived and thrived in these protoplanetary discs more generally and therefore, whether our Solar System just happened to be unusual in terms of its overall chemistry."

However, recent research by Öberg's group at CfA has begun to answer the question by tracking down the signature of such chemicals in the radiation from newly formed stars. The intensive search makes use of the world's largest telescope, the Atacama Large Millimetre Array (ALMA) in Chile. This network of 66 radio antennas on northern Chile's Chajnantor

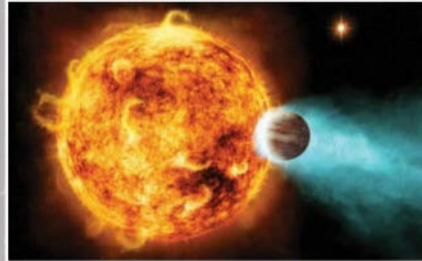
"We know that these kinds of molecules must have been present in the young Solar System" **Karin Öberg**

Prospects for life?

Most stars have planetary systems of one kind or another, but finding the right conditions for life is much more of a challenge

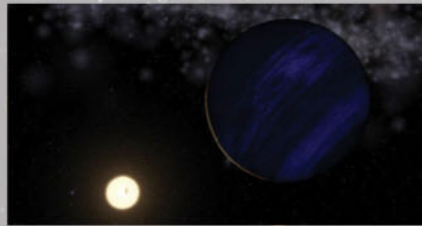
Too close

Many of the exoplanets are in extreme orbits that see their surfaces heated far above the boiling point where any life could survive.



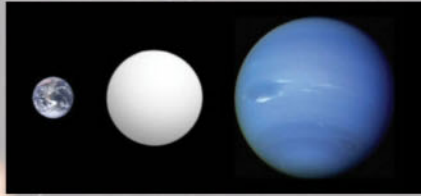
Too hot

If a planet's parent star has significantly more mass than the Sun, then it will burn a lot brighter and produce intense radiations that disrupt complex chemicals and damage the prospects for life.



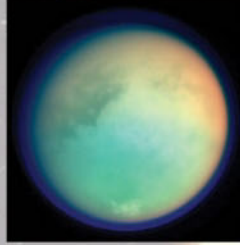
Earth-like worlds

So far only a few Earth-like exoplanets have been discovered, but some astronomers believe there could be as many as one for every star in the Milky Way. Looking for these Earth analogues is important because they hold the most hospitable environments for life.



Giants and their moons

Most of the exoplanets discovered have been gas giants like Jupiter. Their lack of a solid surface makes them an unlikely place to find life, but their moons might be a different story. Several moons in our Solar System have liquid water buried beneath their surfaces, like Titan, which certainly has an exciting abundance of organic chemicals.



Too cold

Stars less massive than the Sun are widespread in the universe and live for many billions of years. However, they may simply not generate enough heat to create hospitable conditions, even on a planet orbiting in close proximity.



Too varied

Other exoplanets follow highly elliptical orbits and transform from furnace to icebox and back as they move around their stars.



The Goldilocks zone

In order to sustain life, a planet must orbit at just the right distance from its star in the Goldilocks zone, where liquid water on its surface does not freeze or boil. Tidal forces can also heat the moons of giant planets, potentially creating worlds with oceans.



Too changeable

Most of the stars in our galaxy are members of binary or multiple systems. Any planet in such a system might find its orbit disrupted, or at least a significant change in the amount of heat it receives at different points on its orbit.



Stars: all you need to know

plateau studies the sky in microwaves, the highest-energy form of radio waves.

Öberg and her colleagues turned ALMA's extremely powerful gaze toward a young star called MWC 480, roughly 455 light years away in a star-forming region around the constellation of Taurus. This obscure and unique star was chosen because the team already knew it was surrounded by a protoplanetary disc.

Specifically, the CfA team searched for microwave emissions at specific wavelengths, characteristic of a molecule called methyl cyanide. "Methyl cyanide is especially interesting because of the cyanide (CN) group attached to it," enthuses Karin. "This turns out to be an excellent starting point when you want to form really complex molecules on the surface of a planet like Earth."

As it turns out, the ALMA observations showed that methyl cyanide is indeed abundant around MWC 480, in fact, there's probably more of it than there was in our own early Solar System. This points to a rather intriguing idea, what if star formation doesn't just concentrate organic chemicals, but actually accelerates their formation by providing an environment that encourages very efficient processes of chemistry?

If young stars do indeed form complete with their own orbiting chemical plant, then the formation of molecules on dust grains is likely to play a key role, just as it does in interstellar space. The mechanism for building organic chemicals is probably quite similar to that for producing water. Building a molecule such as methyl cyanide would require several more chance collisions than simple H₂O, but the process would be vastly accelerated by the more closely packed gas and dust. The evidence so far suggests that not only do organic chemicals survive the process of star formation, but they also tend to thrive on it.

For now, Karin Öberg and her team hope to continue the hunt for more evidence of cosmic chemistry at work in planet forming environments. "We just submitted a proposal to ALMA with the aim of expanding the search, as so far we've looked at a single disc and a single complex molecule, but what we really would like to know is what other molecules are out there, what is their relative abundance and of course, how common this kind of system is. Is this still one of the special ones, along with the solar nebula? Or is it typical that planets form in a cloud of complex organic molecules?"

If the proposed search is successful and organics do turn out to be an abundant constituent of protoplanetary discs, then the subsequent implications would be intriguing and perhaps even profound. Any worlds formed in such an environment should end up with substantial amounts of organic material on their surfaces. And if every world in our Solar System receives a similar starter kit of organic compounds, then more complex biochemical molecules should have a good chance of arising anywhere there is a suitable environment. Life could reasonably be expected to have developed on countless planets and moons throughout our galaxy, as well as in others, including several worlds in our very own Solar System. It would truly be life born among the stars. ■

Star-forming nebula

Nebulae like N90 in the nearby Large Magellanic Cloud galaxy are where stars form and the raw materials for life become concentrated into protoplanetary discs.



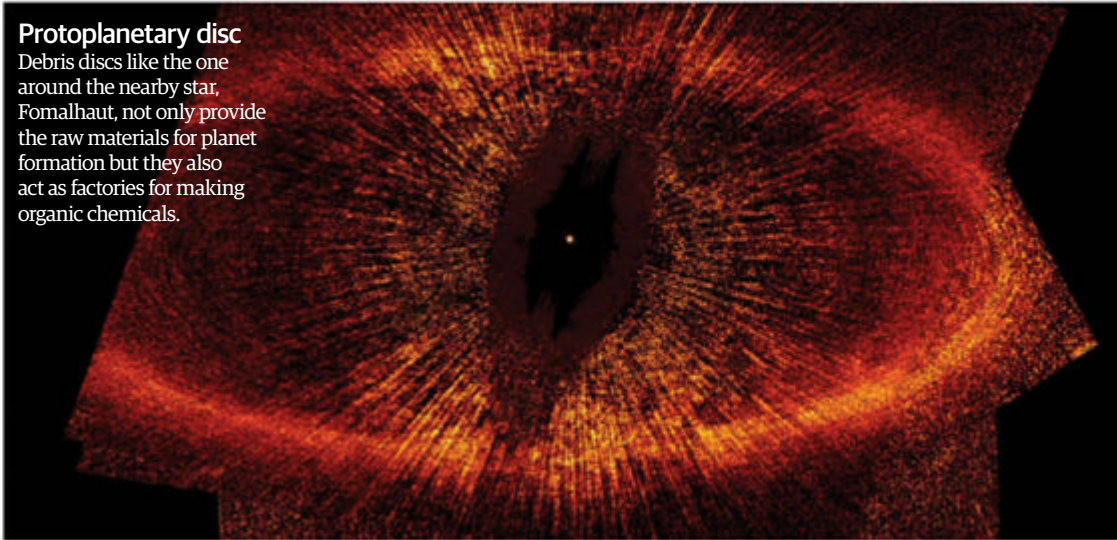
Supernova remnant

The famous Crab Nebula is the aftermath of a supernova explosion seen on Earth more than a 1,000 years ago. It is still expanding at more than 1,500km (932mi) per second, scattering heavy elements over a vast area of space.



Protoplanetary disc

Debris discs like the one around the nearby star, Fomalhaut, not only provide the raw materials for planet formation but they also act as factories for making organic chemicals.



Red supergiants

Giant dying stars like Betelgeuse fling out large quantities of heavy elements in stellar winds and eruptions, even before they go supernova.



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Asteroid nanoprobes

Want to study an asteroid? Then you need a fleet of tiny, flat-packed space probes

Inflatable spheres

The nanoprobes could simply be metallic balloons that would shine by reflected sunlight, tracing bright paths around the gravity field.

The fleet

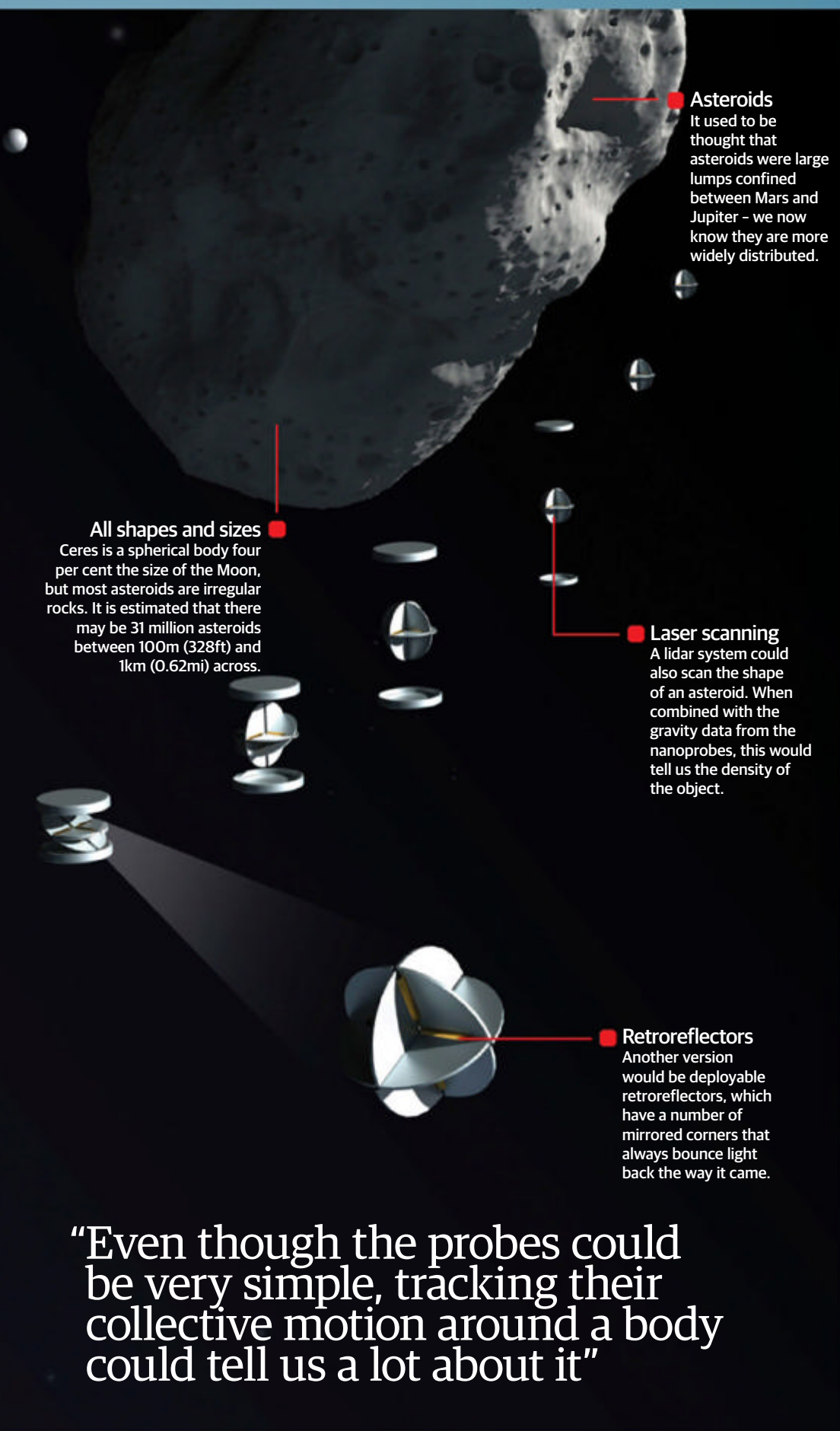
As the group of nanoprobes is deployed toward the asteroid under investigation, they will take slightly different paths as they meet its gravitational influence.

The mother probe

A nanoprobe system would be a tool for a full-sized interplanetary probe like Rosetta, which visited a number of bodies on its adventures.

Lidar

The retroreflectors would work with a lidar on the mother probe. A lidar sends out a laser beam and watches for reflections coming back - like a radar, but with light.



Asteroids
It used to be thought that asteroids were large lumps confined between Mars and Jupiter – we now know they are more widely distributed.

All shapes and sizes
Ceres is a spherical body four per cent the size of the Moon, but most asteroids are irregular rocks. It is estimated that there may be 31 million asteroids between 100m (328ft) and 1km (0.62mi) across.

Laser scanning
A lidar system could also scan the shape of an asteroid. When combined with the gravity data from the nanoprobes, this would tell us the density of the object.

Retroreflectors
Another version would be deployable retroreflectors, which have a number of mirrored corners that always bounce light back the way it came.

“Even though the probes could be very simple, tracking their collective motion around a body could tell us a lot about it”

The landing of the European Space Agency’s Philae probe on the nucleus of comet 67P/Churyumov-Gerasimenko last year, and the arrival of NASA’s Dawn space probe at the dwarf planet Ceres in March, captured the public’s imagination. Philae in particular had to contend with the tumbling, irregular, comet nucleus and had two harpoons and a thruster to try and stick it to the surface. But there are many other smaller bodies floating around in the Solar System that people would also like to study. A researcher at John Hopkins University in Baltimore, USA has a clever idea of how to do just that.

The problem with investigating smaller asteroids is that they are too tiny for a spacecraft to orbit around, so the best we could do is fly past them. But Justin Atchison, a Senior Engineer at JHU’s Applied Physics Laboratory, has proposed to study these objects with swarms of nanoprobes and has received a grant from the NASA Innovative Advanced Concepts programme to develop it.

In Atchison’s concept, rather than having a lander like Philae, a space probe would carry a pack of tiny nanoprobes. These could be flat-packed retro-reflectors (mirrors that always bounce light back in the direction it came from) or shiny balloons that inflate once deployed. The mother probe would direct this group toward the asteroid it wanted to study and then watch their motions as they follow random paths through the asteroid’s gravity field. The shiny balloons would be tracked by a system like the one used for motion capture in filmmaking, where cameras record the paths they trace out. The retroreflectors would be paired with a lidar (like a radar, but with light) on the mother probe, which scans a laser beam around its environment, every time the beam catches a reflector it would get a position measurement back.

Even though the probes could be very simple, tracking their collective motion around a body could tell us a lot about it. That’s because the gravity field of the object, which in turn is governed by its mass and internal composition, will govern their paths. A lidar could be used to scan an asteroid or comet fragment in 3D and this combined with the nanoprobe’s map of its gravity would let us know its overall mass, density, likely structure and composition. A comprehensive catalogue of asteroids and their characteristics will be very important when it comes to tracking and warding off objects that present an impact threat to Earth. It is estimated that there may be as many as 31 million asteroids between 100 metres (328 feet) and one kilometre (0.62 miles) in size.

Atchinson’s team will use the grant over the next year to work on proof-of-concept studies and cost estimates, the nanoprobes have to be cheap as there’s little chance of getting them back. However, they have considered adding an LED illumination to the probes as they could each be assigned different colours to aid camera tracking. Further ahead it may be possible to make them more sophisticated, as the dramatic miniaturisation of computing power and sensor technology offers the prospect of nanoprobes working together to inspect their target. A group of probes could function as a network, taking measurements from all around a target and relaying the data back to the mother probe.

WHAT IF THE

MOON EXPLODED?

and 19 other cosmic questions

All About Space takes a look at the most mind-bending hypothetical scenarios from across our Solar System, space exploration and the deeper universe

Written by Jonathan O'Callaghan

Key

-  Space exploration
-  Solar System
-  Deep space



INTERVIEW BIO

Dr Paul Spudis

Dr Spudis is a lunar geologist for the Lunar and Planetary Institute at NASA. He is an advocate of using the Moon as an exploration port to the rest of the Solar System. In his prosperous time at NASA he has, among other projects, worked on the Lunar Reconnaissance Orbiter mission.

1



"First of all, how would the Moon explode? It might disintegrate due to a giant impact, such as a head-on collision of sufficient energy to break up the Moon.

"A condition of the produced debris would depend on the conditions of impact, a high-velocity impact would mean lots of vapour, which would then rapidly re-condense into billions of cooled droplets of glass. A low velocity collision would include large fragments tens to hundreds of kilometres in size and much of the debris would melt.

"The debris circling the Earth at lunar distance would not be stable, most of it would wander off into solar orbit, while some of it would stay in orbit around the Earth and re-accrete into a larger body.

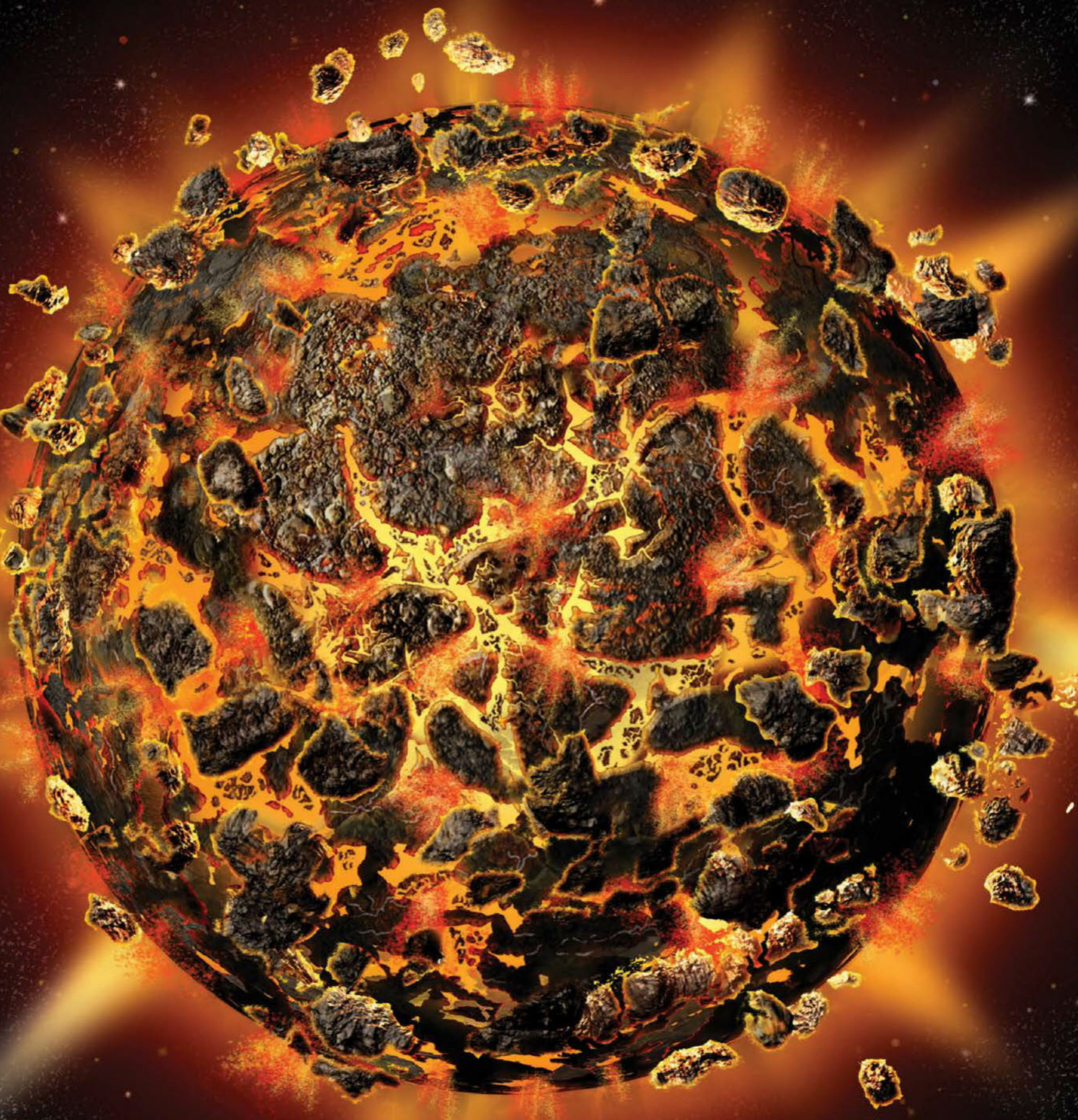
This would occur on time-scales of hundreds of thousands to millions of years.

"Without the mass of the Moon, lunar tides would no longer exist. However, the Earth and its oceans would still experience tides caused by the Sun. They would be of a much lower magnitude, but would still occur twice per day. There would be an immediate mass extinction of some organisms as intertidal species that depend on alternating periods of high and low tide would struggle to survive and adjust to the much smaller solar tides.

"The missing Moon would result in spin axis instabilities for the Earth and the obliquity (the angle from the path of the Sun in the sky) would oscillate wildly."

If the Moon exploded into small pieces, it's possible that over time they would form a ring around Earth, much like Saturn has today





What if the Moon exploded?

Jupiter may have acted like a wrecking ball in the early Solar System, clearing a path for Earth to form

3

WHAT IF ...the Sun disappeared?



If the Sun suddenly disappeared, we wouldn't notice on Earth for 8.5 minutes, until the last of its light reached us. The Moon and the planets, if they were visible, would soon go dark as well, as a wave of darkness - an absence of sunlight - reached them. Within days, Earth would be roughly 100 degrees below freezing, while the atmosphere would freeze and fall to the ground. Exposed to the harshness of space and without the Sun as an anchor, our now surely lifeless planet would be left to drift aimlessly out of the Solar System, along with the rest of our neighbours.



INTERVIEW BIO

Dr Lisa Kaltenegger

Dr Kaltenegger is a professor of astronomy at Cornell University and also director of the Carl Sagan Institute, a research team searching for habitable planets like Earth beyond our Solar System. Her research focuses on the atmospheres of rocky planets and super-Earths in habitable zones.

2 WHAT IF ...Jupiter didn't exist?



"If Jupiter never existed, life on Earth still would still have happened. If there had been heavier bombardment early on then maybe it would have started later, or there could have been more dinosaur-erasing impacts, but the jury on that is still out.

"People argued for a long time that no Jupiter would be a problem because we would have been hit by way more asteroids. But recent work

has shown that Jupiter also deflects asteroids, so they crash into Earth when otherwise they would not have. So it seems it does not make that much of a difference.

"An interesting point in formation is the idea that our Solar System looks like it does because we had Jupiter and Saturn. They basically moved a bit in distance to the Sun during their formation, but not too much and therefore sheltered the inner planets.

"If a big gas giant migrates inward, we find a lot of them close to their stars, so they must have somehow managed to migrate toward it. They cannot be built there and it would destabilise the small rocky planets in that system because of its gravitational pull when it passed by. However, such rocky planets could have formed much later on, after the big gas planets had already migrated inward from the outer Solar System."

WHAT IF

4 ...two supermassive black holes collided?

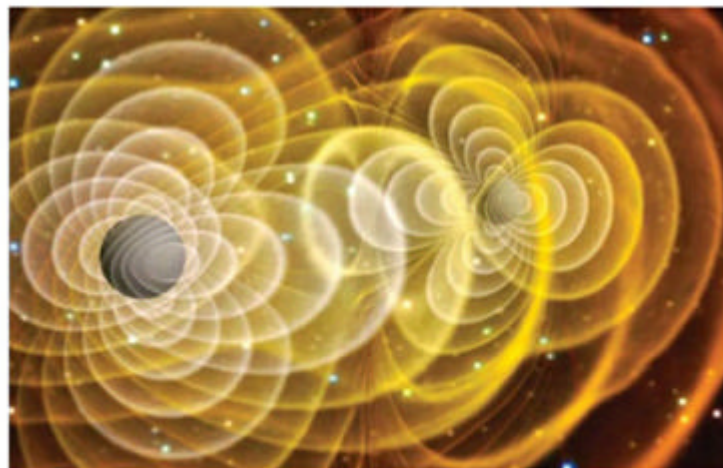


Thanks to simulations, we can make a pretty good guess. In seven years, we'll actually get to observe this happen when two suspected black holes merge into one.

For two black holes to collide, they'll need to already be orbiting pretty close to each other inside a quasar, which is a superheated region of swirling dust and gas. Inside, their gravity carves out a cavity in the surrounding disc, with streams of material feeding the black holes. As they get closer to each other,

these streams actually weaken, a clear sign that a merger is about to happen. In addition, jets of radiation from the poles of the two black holes will merge into one jet. What happens at the point of merging is not known, although it's likely they'd produce noticeable ripples in space-time.

After they have merged, the amount of material being eaten by the black holes increases again, causing aftermath radiation - a sign the merge is complete.



5 WHAT IF ...all the ice on Mars melted?

If you think Mars is a barren, dry world, think again. At its poles, Mars has huge amounts of ice, while at lower latitudes, glaciers survive buried beneath the surface. Recent estimates suggested that there are more than 150 billion cubic metres (5,297 trillion cubic feet) of ice on Mars, enough to cover the entire surface with 1.1 metres (3.6 feet) of ice.

One reason we don't see water on Mars today is that it has only a very

thin atmosphere. Any water that does make it to the surface quickly boils away, owing to the low atmospheric pressure. But if all the ice on Mars were to melt, some theories suggest that it could kick-start a greenhouse effect that would thicken the Martian atmosphere immensely.

If this happened, known as terraforming, it could become possible that water would exist as liquid on the surface. Mars isn't perfectly flat, there

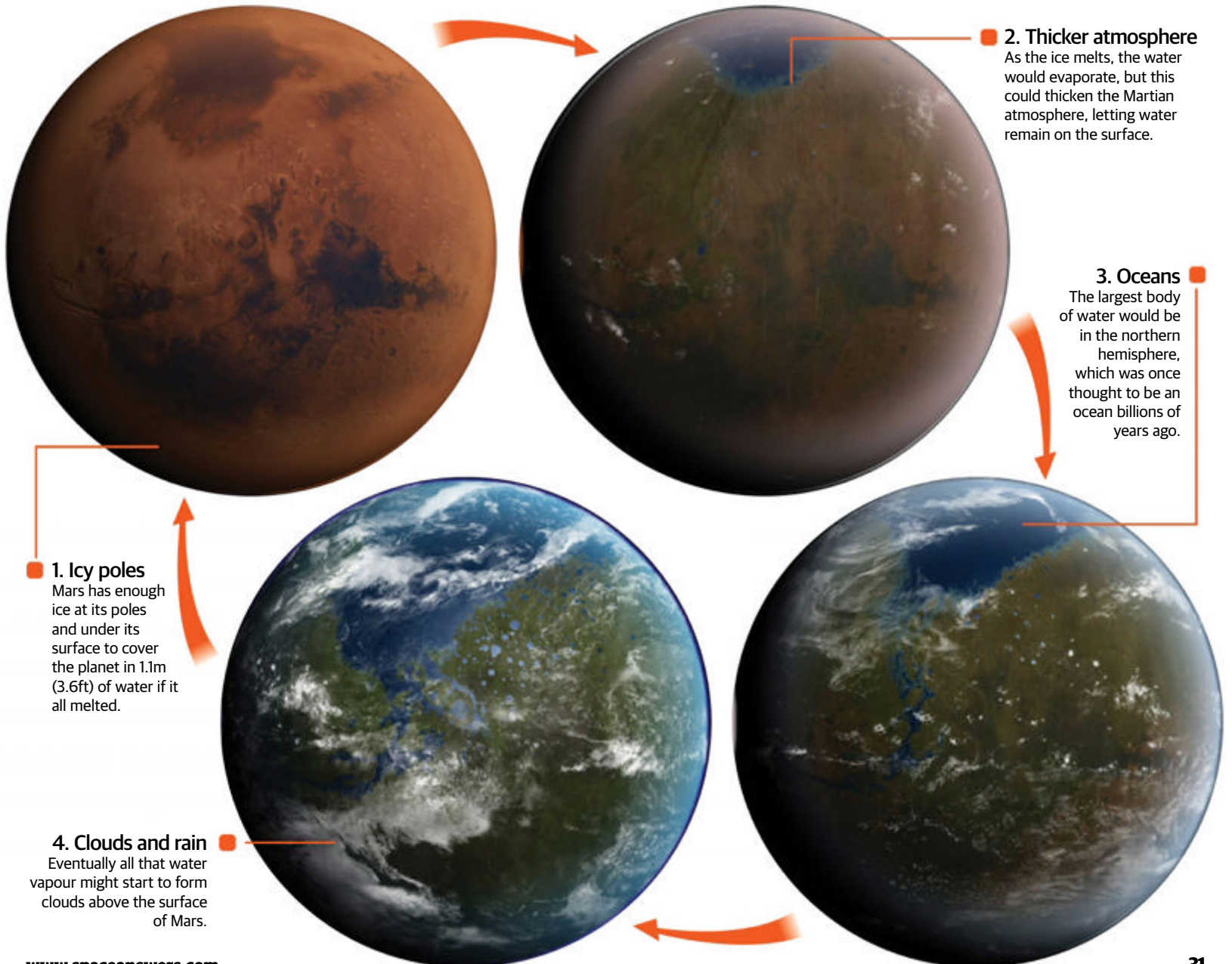
are large craters and canyons, so the water would pool in certain areas creating lakes, seas and maybe even an ocean in the northern hemisphere.

With no plant life on the surface, this water wouldn't kick-start a new era of vegetation. However, it would provide a handy resource for humans.

6 WHAT IF ...Earth stopped spinning?

For anyone not living at the North or South Pole, the first thing they'd notice would be supersonic winds, as the ground stopped but the atmosphere continued to rotate at 1,770 kilometres (1,100 miles) per hour. According to NASA, anything not attached to bedrock would be scoured clean. The resultant waves would decimate every east-facing shore.

Assuming Earth was now tidally locked to the Sun, the remaining life on the planet would have perpetual light or darkness.



What if the Moon exploded?

7

WHAT IF

...we poured a giant bucket of water over the Sun?



If you pour water on a fire here on Earth, it will be extinguished. But the thing to note about the Sun is that it is not burning in the same way a regular fire burns. Instead, it is undergoing nuclear fusion and turning hydrogen into helium, which gives it its heat.

Water is composed of hydrogen and oxygen. Therefore, pouring a giant bucket of water on the Sun isn't going to extinguish it, instead it will cause it to burn much faster and brighter than it already does.

If you had an infinite supply of water, the Sun would start to go through some bizarre stages. One

of these is known as a helium flash, when the amount of helium on the Sun becomes so overwhelmingly intense that a runaway fusion of helium begins to occur.

The ultimate result of continuing to pour water on the Sun is that, eventually, its mass will become so great that it will collapse in on itself and form a black hole. It's possible that before this stage it would expel its now huge outer layers, likely enveloping most of the planets in the Solar System and leaving our charred remain of a planet orbiting what will eventually become a supermassive black hole.

"Pouring a giant bucket of water on the Sun isn't going to extinguish it, instead, it will cause it to burn much faster and brighter"

Pouring enough water on the Sun would cause it to expand from a yellow dwarf into a red giant, before it collapsed into a black hole

8

WHAT IF

...a star near Earth went supernova?



For a star to destroy life on Earth, it would have to be less than 50 light years away. Fortunately for us, there is no star in that range that could go supernova. But if one did, the resultant X-rays and gamma rays would destroy our ozone layer and biosphere, subjecting us to intense ultraviolet rays from the Sun. Such an event would also ionise nitrogen and oxygen in the atmosphere, causing extremely poisonous nitrogen dioxide to form, killing most of the life on our planet.

9...Earth was twice as big?

According to Dr Scott Kenyon from the Centre for Astrophysics (CfA) at Harvard, if Earth were to become twice as massive, it would lose its molten heat from its early years more slowly. "The atmosphere is denser and everything is heavier and requires more energy to move around," he said.

In this scenario, while ants and snakes would be happy, birds might be rare and humans would be shorter and slower. "We would probably know more about the oceans and less about the stars," he added. "Our buildings would be less majestic. But projectiles would require more energy to go less far, so there wouldn't be many wars."

Dr Dimitar Sasselov of the CfA took a different stance: If the Earth was twice as big, its mass would be eight times greater "It would be tough to walk around but it would be a good excuse to spend time on the beach... you're lighter in water!"

What a 100kg person weighs on other worlds



10...space was full of air?

Assuming this air-filled universe was somehow able to remain stable, you'd hear the Sun and nothing else, not even your own thoughts. At Earth's distance, the Sun would deliver around 100 to 125 decibels of noise. That's bordering on the levels that cause physical pain. For any extraterrestrial races orbiting larger stars, it would be much louder and likely cause intense pain, if not death. As for the universe, it would collapse in on itself fairly quickly as the matter would be all over the place.

11 **WHAT IF** ...an astronaut floats off in space?

✦ During a spacewalk on the ISS, astronauts always work in pairs. Each has two safety tethers to stay attached to the station, in addition to numerous handrails to cling on to.

If these tethers failed and they became detached, the astronauts have a redundancy system - the Simplified Aid for EVA Rescue, or SAFER. It is worn like a backpack and uses 24 small jet thrusters to let an astronaut move around in space. "If an astronaut were to become untethered and float away, SAFER would help him or her fly back to the spacecraft," a NASA Spokesperson told **All About Space**.

But we know you're wondering, what if all that fails? Well, that's where things get a bit hairy. If an astronaut floated off from the station and for some

reason the other astronaut couldn't save them, it's possible that the astronauts on the ISS could pilot a Soyuz and pick them up. They wouldn't be able to open the hatch of the Soyuz though, as they wouldn't have time to go through the depressurisation routine, so the astronaut would have to cling on to the side. They must also steer clear of the peroxide thrusters on the side of the Soyuz, which could damage their suit or blast them off into space. When safely dragged back to the station, they could re-enter through the airlock they left from, while the Soyuz returned to dock.

Whether such a manoeuvre is safe, or plausible, is something that NASA and the other space agencies hope they never need to find out.

12 **WHAT IF** ...what if an astronaut took off their helmet in space?

✦ Contrary to what many movies have portrayed, the astronaut wouldn't immediately suffocate or explode. It would take about 15 seconds for your body to use up its oxygen reserves and if you didn't hold your breath, you could survive anywhere up to two minutes. But during this time the water in your body would completely vaporise and the liquid on your tongue would start to boil.

WHAT IF

13 ...the ISS had to be evacuated?

✦ Disaster has struck! A meteor has critically damaged the ISS and the crew must immediately evacuate. What happens?

With two three-seater Soyuz spacecraft docked to the station, the entire crew of six can always return

home. The crew will need to quickly don their re-entry suits and take their places in the Soyuz spacecraft. Each Soyuz can be separated in three minutes and the time from deciding to leave to landing on Earth is about 3.5 hours in total.

However, the ISS would not be lost. It was always designed to operate unmanned if needed, so it could be placed into Assured Safe Crew Return (ASCR) mode, until another crew could be sent. However, without a crew there, it could fall into disrepair.

The safety tethers attaching the astronauts to the ISS can be seen in this picture

14

WHAT IF ...Apollo wasn't cancelled?



During the Apollo programme, many were convinced that the next logical step was to go to Mars. Indeed, at the time NASA had already begun developing a nuclear engine called NERVA (Nuclear Engine for Rocket Vehicle Application), widely viewed as necessary for a Mars mission. But by 1972 the final three Apollo missions: Apollo 18, 19 and 20, had been scrapped and so too had NERVA, with NASA instead focusing on the Skylab space station, the Space Shuttle and ultimately the ISS. Some experts believe, had this not happened, that humans could have already built a permanent base on the Moon.

WHAT IF

15

...NASA had an unlimited budget?



"I see NASA's mission as nothing less than to ensure the survival of humanity. Let's start there. That means understanding Earth, protecting it and extending humanity beyond it, in case something goes wrong with the first two!

"To understand Earth, I'd deploy a large constellation of satellites looking back at Earth with high-resolution

cameras and sensors that provide global coverage 24 hours a day, seven days a week. Data would be accessible directly by the public via the free high-speed internet built into the system. Anyone could access the pictures/data with a host of analysis overlays from their phone, whether looking for a lost child or determining if their crops need water.

"To protect Earth, I'd immediately deploy another constellation of spacecraft throughout the Solar System for the early detection and tracking of comets and asteroids. Those are the threats from beyond

Earth that we could actually do something about.

"To extend humanity, I'd invest a large amount in technology for automation, resource utilisation, long duration propellant storage and transfer, space-based manufacturing, radiation-free power and advanced propulsion. We would have to also to invest in sustainable Earth-to-orbit capability, first with partially reusable rockets, then someday, when technology and politics permit, a space elevator. NASA would then look to pioneer settlements on the Moon and Mars."



INTERVIEW BIO

Dr Patrick Troutman

Dr Troutman is a senior technologist at the NASA Langley Research Center in Hampton, Virginia. He is currently leading the integration of the NASA Evolvable Mars Campaign (EMC), a strategic analysis to develop options for human space exploration.





INTERVIEW BIO

Dr Seth Shostak

Dr Shostak is the senior astronomer and director of the Center for SETI (Search for Extraterrestrial Intelligence) Research. He is a strong advocate for finding out if we are alone in the universe and has been responsible for boosting the profile of SETI.

16 **WHAT IF** ...we found life?

“Many people feel discovering cosmic company would be so disruptive that government agencies would keep the news secret. The public, it's assumed, is not adult enough to hear such things.

“While that scenario plays well with those inclined to believe in conspiracy, the truth is different and demonstrated. A few false SETI alarms have shown us what really happens. The initial reaction would be a rise in the adrenaline level of the scientists involved. They would spend days frantically confirming

that the transmission is really coming from ET. During this time the media will be all over the story, wanting to know whether the detection is real or not. The government, for its part, has never really shown any interest in such signals.

“If we could prove that the discovery was the real deal, then there would be a press conference to announce what we know. Of course, by then all the media will have been running the story for days.

“In the case of the discovery of less imposing life - for example, pond

scum under the rusty landscapes of Mars or beneath the ice of a moon of Jupiter - the scenario would scarcely be different. In both cases, there's no plan to keep secrets. A discovery would simply be a very big story and the public would want to know more.

“In either case, we would learn that life is commonplace in the cosmos. If we were to pick up a radio signal, we'd also know that intelligence is not limited to Homo sapiens. We would finally be able to establish our place in the biological scheme of things.”

Governments have never shown a particular interest in the potential discoveries of alien life

17 **WHAT IF**

...a deadly asteroid threatened Earth?

There are many proposals to deflect an incoming asteroid. These include detonating nuclear weapons on it to divert its path or using a spacecraft to push it out of the way. But none of these methods are ready to launch. If a killer asteroid was heading our way, we'd probably know about it years or decades in advance as NASA and other agencies are pretty good at tracking large objects. But if it was discovered late, with impact only a week away for example, then we're afraid you'd have to prepare for the worst. This is why many groups want to quickly improve our defences.

18 **WHAT IF**

...Earth was closer to the centre of our galaxy?

“If the Sun were located much nearer to the centre of the Milky Way, things would be a bit different for us humans as we orbit here on Earth. The Milky Way would be far brighter and wider in extent in the sky and would display large extended regions of dark dust patches and glowing clouds of gas surrounding newly formed stars, especially as we peer toward to the galactic centre.

“The sky would be filled with hoards of young, bright stars, many

of which would be easily seen in the daytime. Looking toward Sagittarius A, the 4 million solar mass black hole residing in the centre of the galaxy, we would easily detect motion of the stars over time as they orbit the black hole every 15 to 20 years.

“The number of stars nearby to the Sun would be far greater than now and some might come close enough to affect the orbits of the planets in our Solar System, perhaps making the orbits become increasingly elliptical.

“If the orbit of the Earth became significantly elliptical, seasonal changes would depend less on the tilt and far more on the changing distance Earth would be from the Sun. Winters would become much colder and summers far hotter in such a case.

“Occasional close encounters might drive many more comets into the inner Solar System, increasing the chance of impacts and even allowing planets to interact.”



INTERVIEW BIO

Dr Steve Howell

Dr Howell is one of NASA's leading exoplanet experts, having been the project scientist for the hugely successful Kepler mission, which has found thousands of planets in the galaxy.

19 WHAT IF ...the universe wasn't expanding?

 If the universe wasn't expanding, one thing that would be immediately noticeable is that the night sky would be a lot brighter. In 1823 German amateur astronomer Heinrich Wilhelm Olbers pondered the following: if the universe was infinite and static, then the night sky should appear bright, as the light from an infinite number of stars reaches Earth. Of course, as we now know, space is expanding, this problem, known as Olbers' Paradox, is not the case.

If the universe had started in its present state, then we wouldn't see redshift from distant galaxies and the shifting of their light toward one end of the spectrum. In the long term, it's possible that gravity would pull everything in the universe toward each other, perhaps culminating in a 'Big Crunch', the opposite of the Big Bang.

Paradox

According to Olbers' paradox, if stars were evenly distributed we would see them across all points of the night sky.

Light

As we look further and further into the universe, we would see more and more stars, making the night sky brighter.

Expansion

In actuality the universe is expanding, so the amount of light we see is limited.

20 WHAT IF ...there was no gravity?



If there was no gravity since the beginning of time, then simply put, there would be no universe. Without gravity, none of the matter in the universe would have been able to coalesce together into objects like stars and galaxies and perhaps the Big Bang would not have even happened at all. Alternatively, if gravity were ever-present until, say, right now, then everything as we know it would begin to drift apart. Not a pretty sight.

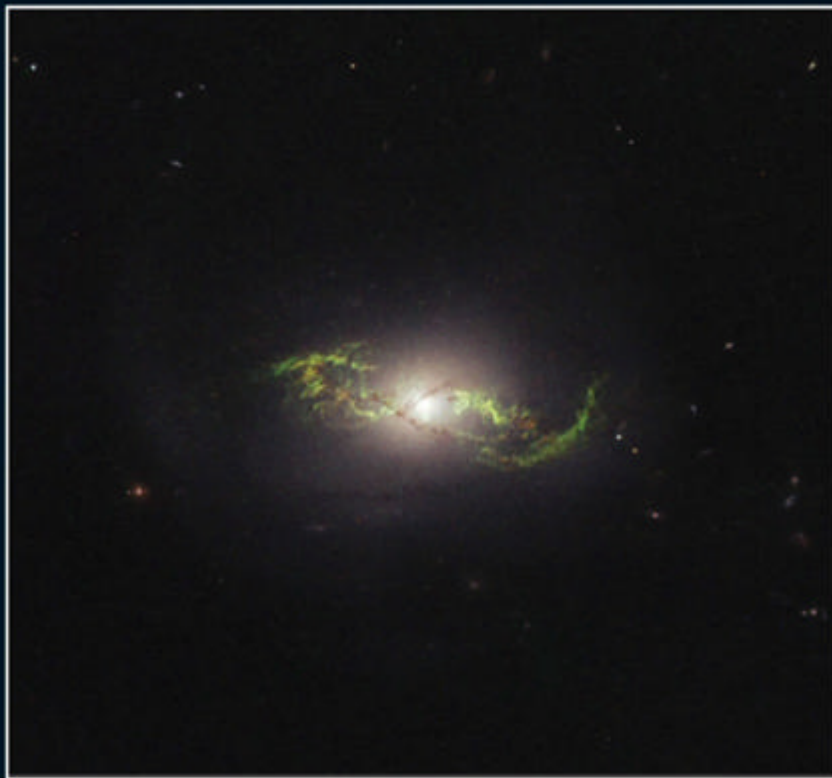
You are here

Our Solar System is at an ideal distance of 26,000 light years from the Milky Way's centre.

Some have suggested our planet orbits in a galactic habitable zone and whether life could survive closer to the centre is currently unknown

Galactic ghosts

Eight shadowy galaxies that were briefly lit up by a powerful blast of energy



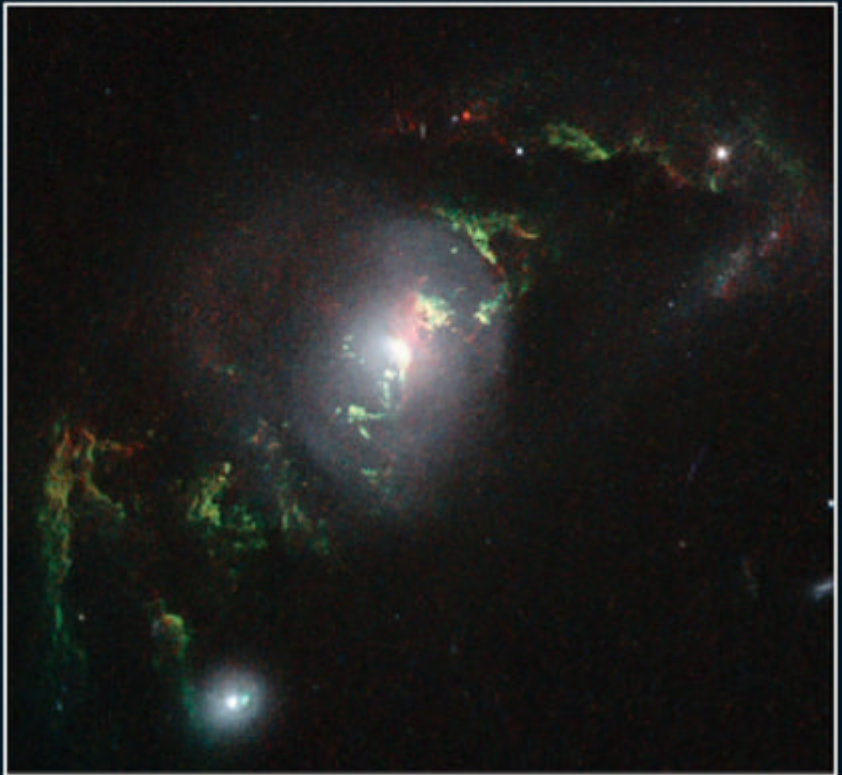
Each of these wispy celestial objects is a galaxy photographed by the Hubble Space Telescope. Most of the filaments that surround them, which show up mainly in green, were practically invisible until the energetic quasar that surrounds the supermassive black hole in their host galaxy lit them up with an extremely powerful blast of radiation. This caused elements in the filaments, including oxygen, helium and sulphur, to absorb the energy and release it gradually as light. Each element glows in a different

colour and green, the most abundant colour in these images, is ionised oxygen. The process is called photoionisation and the filaments will glow for many thousands of years after having been ionised - although this period is just a blink of an eye on a cosmological scale.

The far left image on the top row shows the Teacup galaxy. A supermassive black hole at its core is actually blasting away the raw materials needed for continued star formation. ●

The once-invisible filaments of these galaxies have been illuminated by the radiation that surrounds their supermassive black holes

© ESA



USER MANUAL

Rosetta spacecraft

Written by Dominic Reseigh-Lincoln

THE SPECS

Launch: 2 March 2004

Launch rocket: Ariane 5

Target: Comet 67P/

Churyumov-Gerasimenko

Operators: ESA

Orbital insertion: 6 August 2014

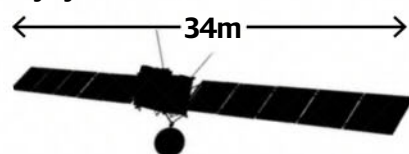
Component: Philae lander

Probe landing: 12 November 2014

Mission ends: December 2015

Current time at 67P/C-G: 9 months

Flybys: Mars, 2867 Šteins, 21 Lutetia



→ Average human height

The Rosetta spacecraft and its lander twin Philae may be named after objects steeped in ancient history (the Egyptian Rosetta Stone and the Egyptian/Greek Philae Obelisk, to be precise), but both represent some of the most advanced robotics ever sent into the deep, dark depths of space. Having arrived at their destination, the dynamic duo would not only be the first craft to successfully orbit a comet, but went on to provide the most comprehensive study of such a celestial body.

Its origins can be traced back to 1986, when Halley's Comet made its most recent pass of the Earth in a loop that brings it within sight of our planet every 75 years. With such a considerable amount of time between each sighting, the opportunity to study the comet was too tempting to pass up by the space agencies of the world. Several space agencies sent probes to meet it, including the ESA's Giotto

craft, with each one providing reams of valuable scientific data on its nature and composition. With the information to hand, it was clear to both agencies that further missions could yield even more fascinating discoveries, so new programs were green-lit to follow up the Halley mission.

Renewed fervour didn't lead the ESA directly to the Rosetta program, but it set into motion a chain of events that would see the mission come to fruition. As the 1980s drew to a close, NASA began working on its Comet Rendezvous Asteroid Flyby (CRAF), while ESA focused on its Comet Nucleus Sample Return (CNSR) programme. In 1992, NASA pulled funding from its CRAF project but ESA decided to push on. Eventually the Agency would reach the same roadblock, with research and design costs spiralling well beyond what its multinational funding could afford.

"Its origins can be traced back to 1986, when Halley's Comet made its most recent pass of the Earth"



The Philae lander separated from the Rosetta orbiter at 8.35am (GMT) on 12 November 2014. It landed on 67P at 3.34pm, bounced twice and finally settled at 5.32pm



The Rosetta spacecraft sporting thermal blankets in the clean room, ready for testing at the Large Space Simulator

Anatomy of Rosetta

Studying comets requires an impressive array of high-tech tools

Micro-Imaging Dust Analysis System (MIDAS)

Similar to COSIMA, the MIDAS instrument uses an atomic force microscope to study the detailed composition of the comet's dust build up.

Microwave Instrument for the Rosetta Orbiter (MIRO)

MIRO uses microwave emissions to detect the presence of substances such as carbon dioxide, water and ammonia in the atmosphere.

Cometary Secondary Ion Mass Analyser (COSIMA)

One of four instruments created to study the dust and particles found in the coma (atmosphere) of the comet. COSIMA is used to study the overall composition of the comet's surface.

Rosetta Orbiter Spectrometer for Ion and Neutral Analysis (ROSINA)

Developed by the University of Bern in Switzerland, ROSINA is a vital part of Rosetta's toolset. It measures the temperature, velocity and density of the gas flow found in the comet's surrounding ionosphere.

Grain Impact Analyser and Dust Accumulator (GIADA)

Another dust-centric tool inside Rosetta, GIADA studies the number, momentum, mass and velocity distribution of dust particles in the comet's coma.

Visible and Infrared Thermal Imaging Spectrometer (VIRTIS)

Using a specialised IR spectrometer, VIRTIS is able to capture images of the comet's atmosphere as it searches for an infrared spectrum of dust molecules.

Optical, Spectroscopic and Infrared Remote Imaging System (OSIRIS)

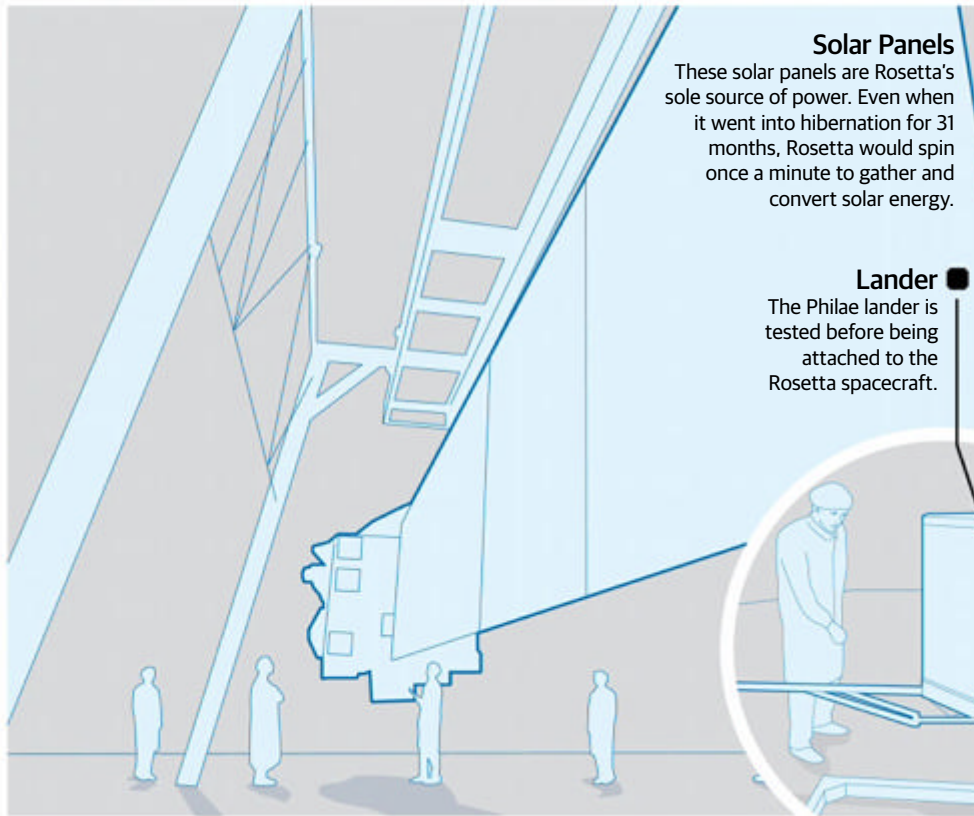
Comprised of a wide-angle camera (WAC) and narrow-angle camera (NAC), OSIRIS is used to snap shots of the visible, near-infrared and ultraviolet wavelengths of the comet.

Rosetta Plasma Consortium (RPC)

Designed to study the plasma environment of the comet, it uses a number of smaller sensors including the Langmuir Probe (LAP) and a Fluxgate Magnetometer (MAG).

Ultraviolet Imaging Spectrometer (ALICE)

Designed by NASA for use on Rosetta, ALICE exists to study the presence and activity of noble gases in the comet's nucleus, which in turn helps discern the temperature at which it was formed.



Solar Panels

These solar panels are Rosetta's sole source of power. Even when it went into hibernation for 31 months, Rosetta would spin once a minute to gather and convert solar energy.

Lander

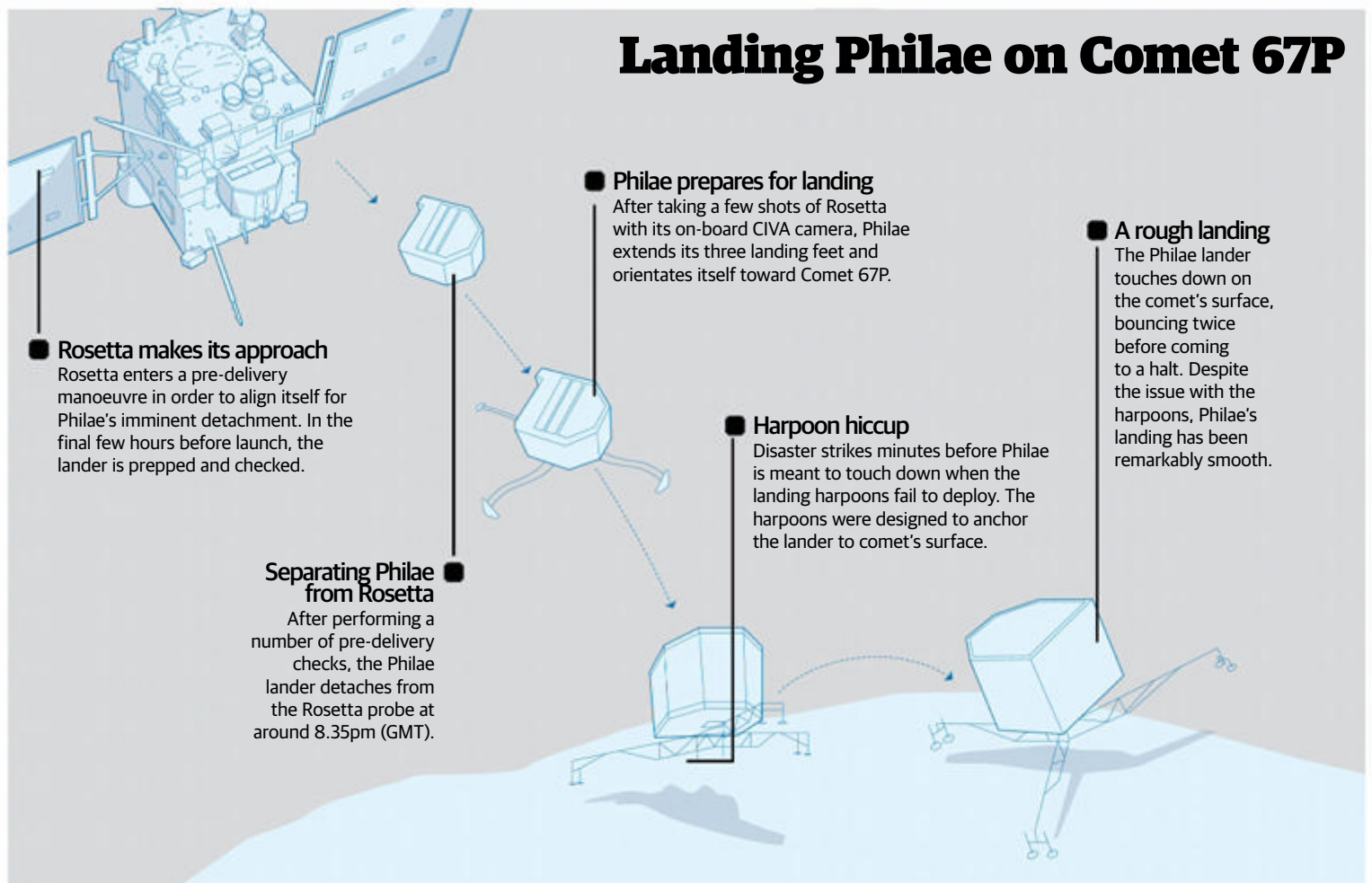
The Philae lander is tested before being attached to the Rosetta spacecraft.

Thankfully, seven years of research and development didn't go to waste and in November 1993 the ESA commissioned the far smaller, but no less ambitious International Rosetta Mission. This project would be a cornerstone mission in its Horizons 2000 Science Programme and one that would aim to curate the most in-depth data of a comet ever gathered.

The programme consisted of two separate craft: the first was Rosetta, a space probe drawing inspiration both from NASA's early Mariner Mark II design and new developments in unmanned space exploration. The second would be a lander called Philae, constructed to land on an extraterrestrial surface and gather data that could be fed back to Rosetta, then beamed back to the project's scientists and engineers.

ESA pencilled in a preliminary 12 January 2003 launch date, giving the multinational team just under a decade to bring Rosetta and Philae to fruition. The date was chosen because it would give Rosetta time to travel across the Solar System and rendezvous with Comet 46P/Wirtanen in 2011. It was pushed back when the Ariane 5 carrier rocket, the propulsion design that had powered most of ESA's space programmes, failed

Landing Philae on Comet 67P



Rosetta makes its approach

Rosetta enters a pre-delivery manoeuvre in order to align itself for Philae's imminent detachment. In the final few hours before launch, the lander is prepped and checked.

Separating Philae from Rosetta

After performing a number of pre-delivery checks, the Philae lander detaches from the Rosetta probe at around 8.35pm (GMT).

Philae prepares for landing

After taking a few shots of Rosetta with its on-board CIVA camera, Philae extends its three landing feet and orientates itself toward Comet 67P.

Harpoon hiccup

Disaster strikes minutes before Philae is meant to touch down when the landing harpoons fail to deploy. The harpoons were designed to anchor the lander to comet's surface.

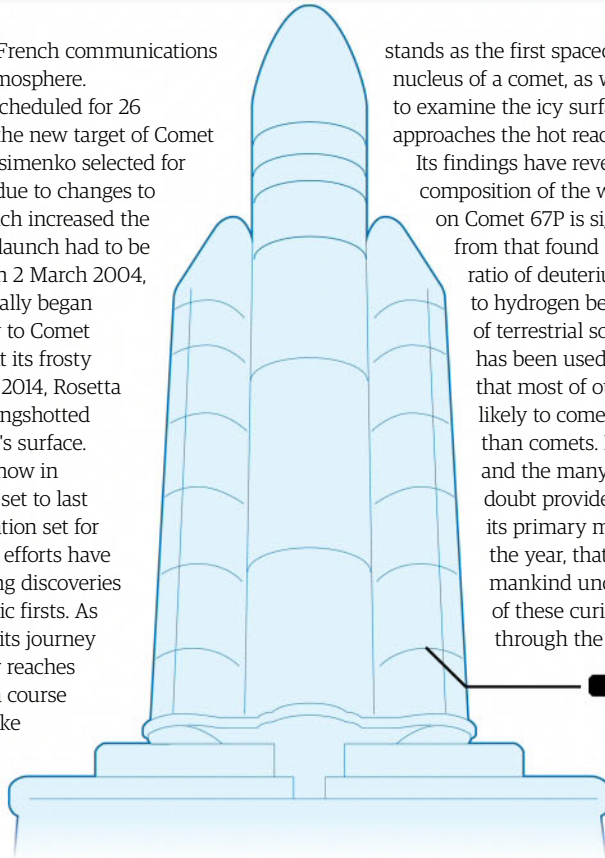
A rough landing

The Philae lander touches down on the comet's surface, bouncing twice before coming to a halt. Despite the issue with the harpoons, Philae's landing has been remarkably smooth.

to carry Hot Bird 7 (a French communications satellite) out of our atmosphere.

The launch was rescheduled for 26 February 2004, with the new target of Comet 67P/Churyumov-Gerasimenko selected for study. Unfortunately, due to changes to the rocket design, which increased the mass of the craft, the launch had to be scrapped again. But on 2 March 2004, Rosetta and Philae finally began their ten-year odyssey to Comet 67P. When it arrived at its frosty destination in August 2014, Rosetta went into orbit and slingshotted Philae onto the comet's surface.

With the two craft now in place, their mission is set to last a year, with a culmination set for December 2015. Their efforts have gathered some startling discoveries as well as some historic firsts. As Comet 67P continues its journey into the warmer inner reaches of the Sun's domain, a course that will eventually take it around our star and back out into the inner Solar System, Rosetta



stands as the first spacecraft to orbit the nucleus of a comet, as well being the first craft to examine the icy surface of a comet as it approaches the hot reach of a star.

Its findings have revealed that the composition of the water vapour found on Comet 67P is significantly different from that found on Earth, with the ratio of deuterium (heavy hydrogen) to hydrogen being three-times that of terrestrial sources. This evidence has been used to support the theory that most of our planet's water is likely to come from asteroids rather than comets. It's these findings and the many more that it will no doubt provide before it completes its primary mission at the end of the year, that will continue to help mankind understand the nature of these curious icebergs hurtling through the depths of space. ■

■ Scrubbed launch

Rosetta was launched on an Ariane 5 carrier rocket on 2 March 2004 after two scrubbed launch attempts from the Guiana Space Centre in French Guiana.

HOW TO...

Wake up a spacecraft

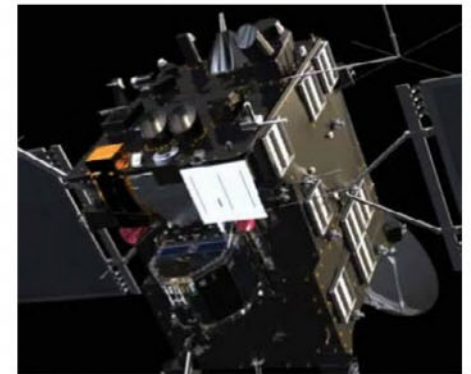
1 Warming up

At a distance of 673mn km (418mn mi) from the Sun, Rosetta prepares to awaken from its 2.5 year slumber. This process begins with the warming up of its Sun trackers – two optical devices measuring its distance from the Sun.



2 Reassessing its inertia

Next, the probe fires its thrusters to slow its rotation, positioning its solar panels toward our home star. Now in a state of slower rotation, its star trackers (highlighted in red) locate the Earth in order determine Rosetta's attitude.



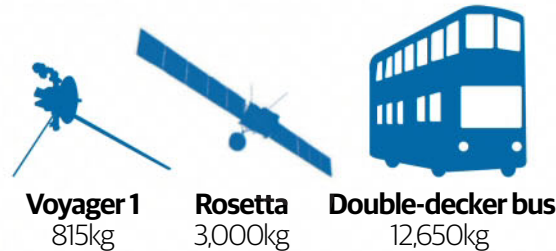
3 Touching base with Earth

After aligning its solar panels and antennas toward Earth, Rosetta begins sending out a wake up signal to the ESA's European Space Operations Centre. They then bounce a confirmation back and Rosetta to begins its final phase of travel.



Head to head

The Rosetta space probe is definitely on the chunkier side. At launch it weighed around 3,000 kilograms (6,614 pounds), but shed a lot of weight once it jettisoned its payload. By comparison, Voyager 1 was around 815 kilograms (1,797 pounds) and a bus weighs four-times as much.



TOP TECH

Solving the mystery of Comet 67P

Of all the tech on Rosetta, its Ultraviolet Imaging Spectrograph is perhaps its most pivotal. Dubbed ALICE, this NASA-designed device tests and quantifies the presence of noble gas in the comet's nucleus, enabling NASA and ESA to determine its temperature. It also measures the ultraviolet light spectra of the comet and tests the hydrogen and oxygen in its atmosphere.



ALICE is used to measure gases in the comet's coma

Vital statistics

10 years = That's around 13 lunar orbits
Time it took to travel to Comet 67P

15 = nearly half the countries in the World Cup
Countries contributed to the Rosetta space probe

€1.4 billion = That's 38 Empire State buildings
Estimated cost of Rosetta space probe program

31 months = 4x longer than a grizzly bear
Rosetta went into a hibernation state for over 2.5 years



SPACE VOLCANOES

From Venus to Mars and the moons around far-flung planets, volcanoes have helped shape the celestial bodies of our Solar System

Written by David Crookes



It was 2 March 1979 and the work of planetary scientists Stan Peale, Patrick Cassen and RT Reynolds was beginning to land on the desks and doormats of thousands of astronomers. Published in the journal, *Science*, the academic paper predicted one of Jupiter's four major moons, Io, was far from geologically dead. It stated evidence pointing to a celestial body that could be teeming with volcanic activity and as it turned out, the scientists were more than correct.

Three days later on 5 March, Voyager 1 - a spacecraft launched in the late summer of 1977 - made its closest approach to Jupiter as it journeyed to unlock the hidden secrets of the Solar System's outer planets. What it discovered astounded Voyager 1's navigators at the Jet Propulsion Laboratory in California. Not least of all, astronomer Linda Morabito, who had been analysing an image taken by the spacecraft for navigation purposes and saw a puzzling feature that turned out to be a volcanic plume off the limb of Io. It was 270 kilometres (170 miles) tall, spewing sulphur into the airless sky with great ferocity, forming a persistent red ring of deposits. This volcano came to be known as Pele, after the Hawaiian fire goddess and its discovery was to be hugely significant: it was the first time that an erupting

volcano had been found anywhere other than Earth.

As such, astronomers focussed their attention further on Io. It wasn't the first time that alien volcanoes had caught the imagination. Missions to the Earth's Moon had uncovered basalt samples some 3.3 billion years old and Apollo 15 had landed close to Hadley Rille, an immense groove on the Moon 1.5 kilometres (0.9 miles) wide and 300 metres (984 feet) deep. This groove likely originated as a lava tube whose roof collapsed. The unmanned spacecraft, Mariner 9, highlighted a varied Martian terrain in 1977, which had huge volcanoes including the mammoth Olympic Mons. Yet, like the volcanoes of Mercury, these discoveries were all completely extinct.

Io proved to be a myriad swirl of colours thanks to a thin atmosphere laden with sulphur. It was showing signs of being the most geologically active body in the Solar System and over the years, more than 150 active volcanoes (of more than 400 volcanoes in total) have been discovered there. Some of the moons of Saturn

and Neptune (Enceladus and Triton) have active volcanoes, Venus too, as well as the Jovian moon Europa. All of these have the potential to divulge fresh information. "Although we have volcanoes on Earth, you have to study somewhere different to understand the big picture," says Dr Rosaly MC Lopes, a senior research scientist at NASA's Jet Propulsion Laboratory. "If you just look at your own little corner, you will not know what is possible."

Dr Lopes became interested in volcanology during her studies in astronomy at the University of London, becoming particularly hooked when Mount Etna exploded and her volcanology professor did not show up, "I thought it was really exciting to work on something where you had to rush off like that," she says. Following her graduation she worked on the Galileo Flight Project, a mission to Jupiter that launched in 1989. She studied infrared data from Io that allowed her to detect the heat from the volcanoes. Between 1996 and 2001 she discovered 71 active volcanoes, a feat which earned her an entry in the *Guinness Book Of World Records* as the person to have spotted more active volcanoes than anyone else.

"Io has sulphur dioxide pretty much everywhere," Dr Lopes explains. "So you have to detect either

"I would compare the pixels of the images we received, looking for infrared hotspots that were different to the surroundings"

Dr Rosaly Lopes, NASA's Jet Propulsion Laboratory

Io: the Solar System's most volcanic world

Discover some of the many volcanic systems littering the surface of Io

Io's surface is covered with sulphur, giving the moon its colourful patchwork appearance

Amaterasu Patera

Paterae are shallow volcanic craters and Io has many of them. Amaterasu Patera measures 100km (62mi) in diameter and it is one of Io's darkest features. Its activity has been persistent over years of observations.

Loki Patera: Io's largest caldera

Known to be Io's most active hot spot, Loki Patera is the Solar System's most powerful volcano. Its heat can be detected from Earth and its depression is 200km (124mi) in diameter.

Fuchi Patera

Named after the Ainu fire goddess Kamuy Fuchi (all of the paterae are named after Sun and fire gods), Fuchi Patera is around 64km (40mi) in diameter.

The sulphur ring of Pele

First observed in 1979 by Voyager 1, Pele is ringed with red sulphur deposited by its plume. Astronomers believe it is an active lava lake since there is a very intense hot spot.

Babbar Patera

Situated in the south polar region, in relative proximity to Pele, Babbar Patera shows dark deposits that scientists say are likely to include orthopyroxenes that are rich in magnesium.

the heat, plume, or a surface change to show that a volcano is active. The easiest way is to detect heat, so I would compare pixels of the images we received, looking for infrared hotspots that were different to the surroundings. We had limits of resolution and it was a lot of work but it was not that hard."

There are different types of volcanoes in the Solar System. Shield volcanoes are built up of fluid lava flows and they have broad, low-profile features. Composite volcanoes are conical, built up of ash, rock, dust and hot steam. Depending on their location in space, they either spew molten silicate rock magma or, as is the case beyond Mars, cold or frozen gases including water, ammonia or methane.

What's more, volcano activity can be short or long-lived, continuing to spew for decades at a time. For instance, the volcanoes on Io stay active for very long periods of time. "They are much more powerful than the volcanoes on Earth," says Dr Lopes. "When Voyager 1 flew past in 1979 about a dozen volcanoes were active. When Galileo visited in the late 1990s and early 2000s most of these volcanoes were still active and there were detections from the ground in-between. In July last year, the New Horizons voyage to Pluto used Jupiter as a gravity assist and we did some observations of Io at that time - again, some of the very same volcanoes were still active."

She continues: "There are some volcanoes on Earth that are always active on land. There are also volcanoes under the ocean that are harder to find. Certainly Io's volcanoes have the largest heat output and the largest calderas (craters formed by volcanic eruptions or the collapse of surface rock into a vacant magma chamber). Io is considered to be one of the most volcanically active bodies that we know of."



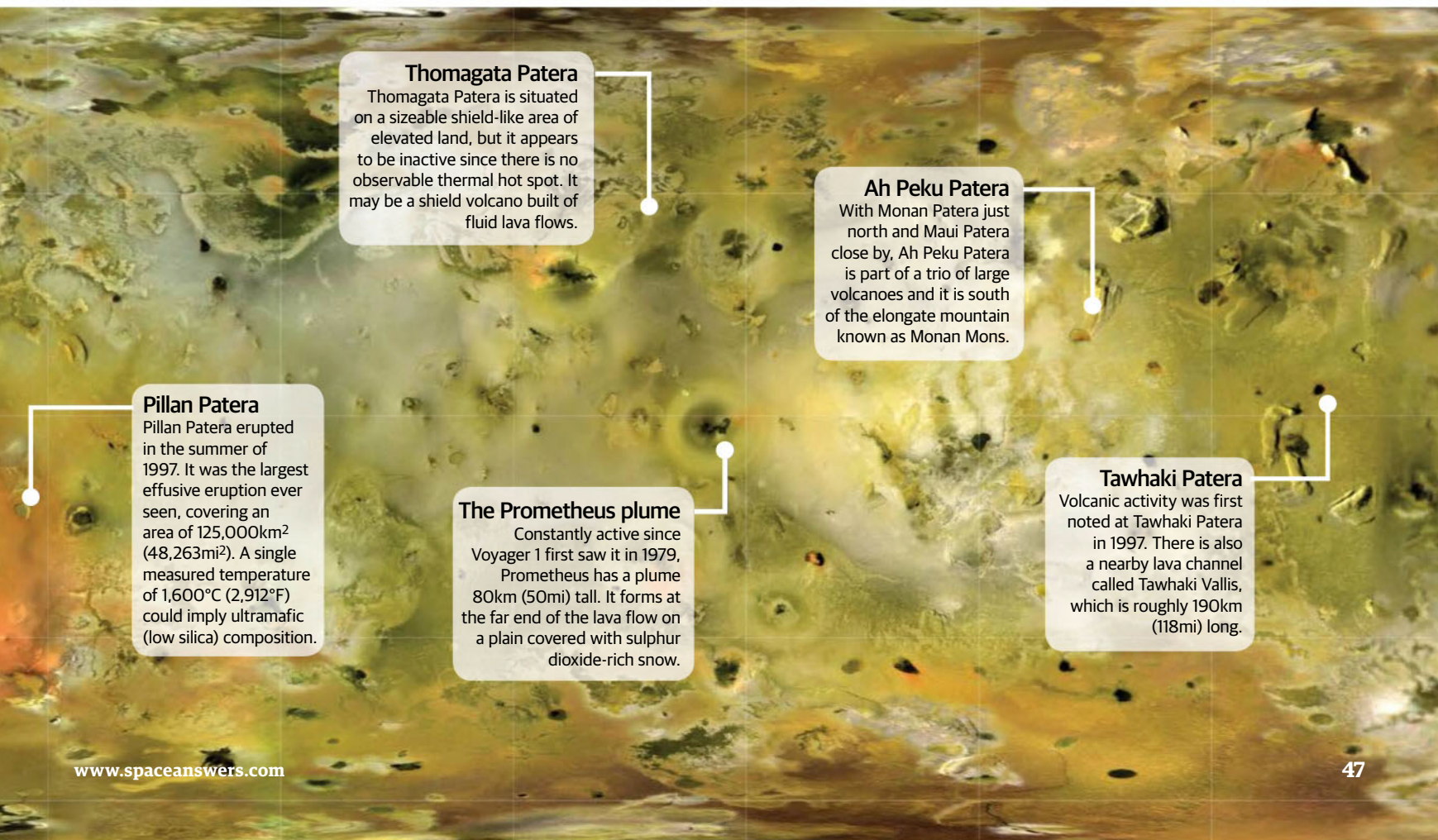
Io's volcanoes are very different compared to Earth's

The most unusual volcano on Io is Loki Patera. It is the most powerful and has the largest volcanic caldera in the Solar System. There is also potential evidence of a lava lake, usually a rare occurrence but seemingly common on Io. "We want to know what is creating these lava lakes and how the eruption mechanisms work," says Dr Lopes. "Loki Patera has some peculiar patterns, an almost cyclical pattern of eruptions that we thought we understood but then stopped... that's what happens when you study a volcano named after a trickster god!"

How explosive a volcano is depends on the composition and the amount of gasses dissolved in the magma. It is often compared to shaking up

a fizzy drink bottle and opening it: if the drink has been allowed to go flat, it is likely to come out with less ferocity than one with its full soda potential. "In a volcano, you get these gasses that are dissolved in the magma," says Dr Lopes. "When magma rises toward the surface, the pressure becomes less and the gasses want to come out. If the lava is very viscous or sticky, the gasses cannot escape easily and eventually they will come out explosively. You can get what we call a Hawaiian-type eruption where you may have this beautiful lava oozing in fountains."

Interestingly, there are differences in the ways similar types of volcano behave according to where they are. On Earth, there is a relatively thin crust that



Thomagata Patera

Thomagata Patera is situated on a sizeable shield-like area of elevated land, but it appears to be inactive since there is no observable thermal hot spot. It may be a shield volcano built of fluid lava flows.

Ah Peku Patera

With Monan Patera just north and Maui Patera close by, Ah Peku Patera is part of a trio of large volcanoes and it is south of the elongate mountain known as Monan Mons.

Pillan Patera

Pillan Patera erupted in the summer of 1997. It was the largest effusive eruption ever seen, covering an area of 125,000km² (48,263mi²). A single measured temperature of 1,600°C (2,912°F) could imply ultramafic (low silica) composition.

The Prometheus plume

Constantly active since Voyager 1 first saw it in 1979, Prometheus has a plume 80km (50mi) tall. It forms at the far end of the lava flow on a plain covered with sulphur dioxide-rich snow.

Tawhaki Patera

Volcanic activity was first noted at Tawhaki Patera in 1997. There is also a nearby lava channel called Tawhaki Vallis, which is roughly 190km (118mi) long.

is divided into several plates gliding over the mantle. This is referred to as plate tectonics. The crusts slowly move, crash and slide into each other, propelled by the incredible heat simmering below them. When one plate is forced below another in a process called subduction, the magmas that come out in those places tend to be more viscous, forming explosive cone-shaped volcanoes. When they pull apart, more fluid basaltic lava comes out creating shield volcanoes that erupt effusively, rather than violently.

Plate tectonics are an alien concept on Io, where volcanic activity originates from the tidal forces associated with its planetary neighbour, Jupiter. Io was not expected to have volcanoes since it is a small body and should have cooled a long time ago, like Earth's Moon. But as it rotates around Jupiter it is effectively squeezed as it gets closer to the planet, then moves away. Its surface is constantly being bent and flexed, which creates the necessary heat for volcanism. It's like taking a ball of wax and massaging it, making it hotter and hotter inside.

"It's unusual because Io is around the size of the Earth's Moon and it should have lost a lot of its primordial heat just like the Moon has - it should have cooled down," says Dr Lopes. "But Io is in a peculiar orbit and it has the gravitational pull of Jupiter. At the same time, the other satellites further away from Io are also experiencing this pull. The constant tug-of-war causes friction, creating heat and ensuring the interior of Io remains very molten. That is what drives volcanism on this moon."

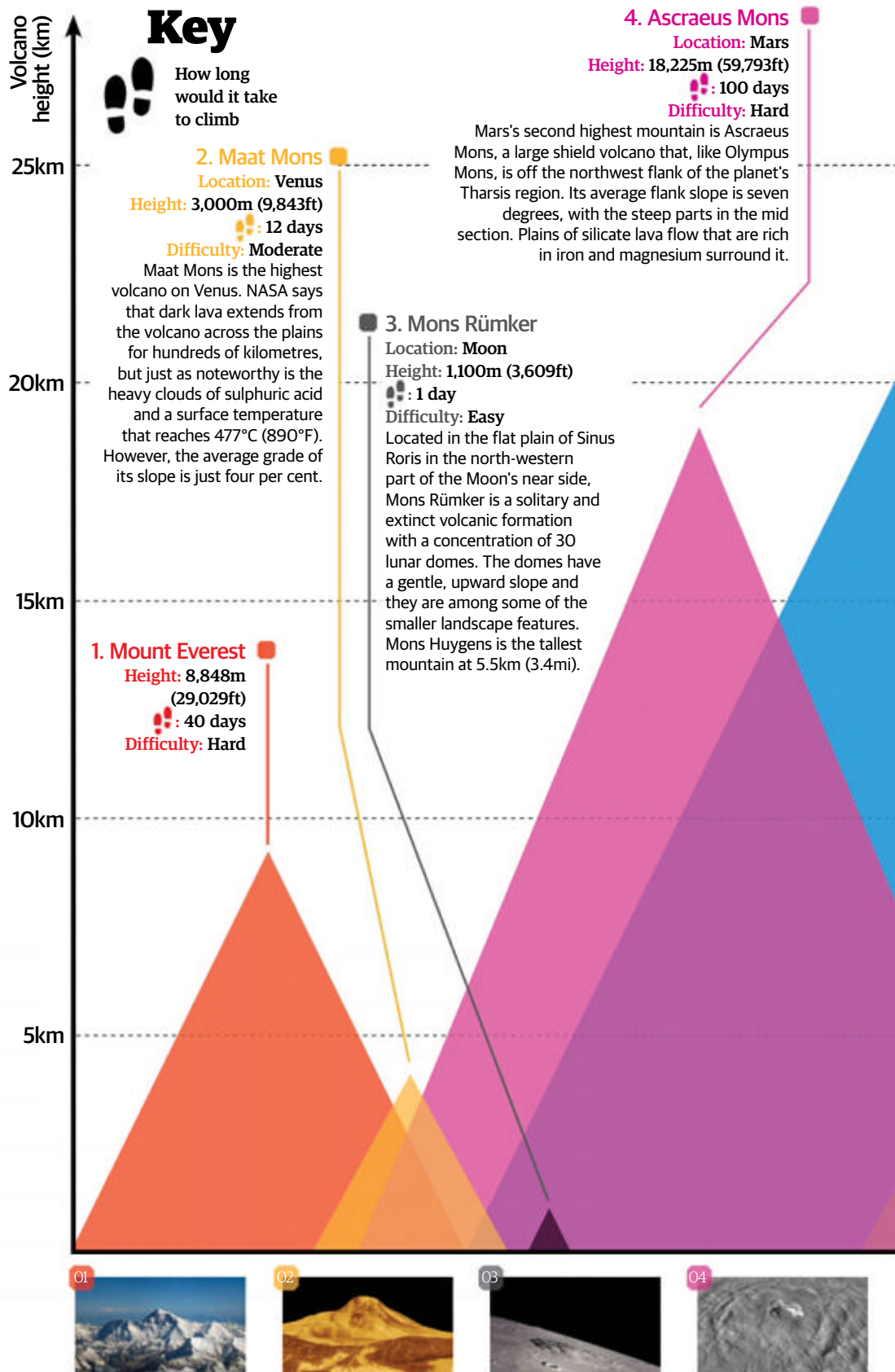
As the volcanoes erupt on Io, it affects the entire Jovian system (the system of Jupiter's 67 known moons). The plumes, says Dr Michael Khan who works in the mission analysis office of the European Space Operations Centre at ESA, produce a ring of charged material around Jupiter and "creates a very nasty environment" as around two trillion watts of power is generated. "All of the stuff gets electrically charged and if you want to fly a spacecraft there, it gets hit by the charged particles and all of the electronics fry. It's not a nice thing to happen."

But the differences between volcanoes on different planets go beyond the causes of activity. Even patterns of eruption can be dissimilar, as is the case on Venus. "Venus can go hundreds of millions of years with no activity," says Dr Khan, "and then everything goes off at once and the surface is completely remodelled." Volcanoes cover around 90 per cent of Venus and its surface has been transformed by volcanic eruptions. According to Dr Lopes, who documented planets in her book, *Alien Volcanoes*, the Magellan spacecraft found Venus's volcanism to be young in geological terms. "There are about 1,000 volcanoes but I haven't counted them," she laughs. "The surface is really volcanic but we don't know that much about it because it's a very challenging environment. The same is true of Io as the environment is very radiation intensive."

Planetary volcanism can mimic that of the moons too. For instance, Mars has dozens of volcanoes that are large and dominant and this is believed to be due to lower surface gravity. A thicker crust and higher eruption rates allow lava to pile on top of lava, creating extra height and bulk. Olympus Mons is 25,000 metres (82,021 feet) high. Not only is it three-times as high as Mount Everest, but its footprint

9 space peaks challenge

With weak gravity, the need for space suits and unfamiliar terrain, climbing the Solar System's volcanoes is the ultimate test



Fast fact

Time it takes to complete the entire challenge, including travel time: **Six years**

5. Olympus Mons

Location: Mars

Height: 25,000m (82,021ft)

🚶: 120 days

Difficulty: Easy

This shield volcano may be the tallest peak in the Solar System, but with a very gentle slope it gives the impression you are walking on a relatively flat surface. Once you reach the summit, marvel at the six nested calderas that make a depression of 60 x 80km (37x 50mi).

6. Arsia Mons

Location: Mars

Height: 16,000m (52,493ft)

🚶: 80 days

Difficulty: Moderate

Also in the Tharsis region is Arsia Mons. Since it is a shield volcano, the slope is relatively low. Research has suggested that it may have been one of Mars's most habitable environments as its slopes were once covered in glacial ice. Its caldera is rather circular, certainly in comparison to the irregularity of Olympus Mons.

7. Pavonis Mons

Location: Mars

Height: 14,000m (45,932ft)

🚶: 70 days

Difficulty: Hard

The smallest of the large shield volcanoes in the Tharsis region is Pavonis Mons. Its gently sloping flanks average four degrees and there is evidence of lava tubes on the surface. These are caused by the lava crust cooling and collapsing as the flowing lava beneath it runs dry.

8. Elysium Mons

Location: Mars

Height: 13,900m (46,000ft)

🚶: 70 days

Difficulty: Hard

As well as the Tharsis region, there are three large volcanoes in the Elysium Planitia area. It includes Hecates Tholus, Albor Tholus and Elysium Mons, which is the largest volcano in this region with a base dimension of 420 x 500 x 700km (260 x 310 x 435mi). Its flanks are steeper than the shield volcanoes, making it a tricky climb.

9. Io volcano

Location: Io

Height: 18,200m (59,711ft)

🚶: 80 days

Difficulty: Hard

It has not been possible to measure the height of Io's 400 volcanoes as yet but this moon does have the largest non-volcanic mountain in the Solar System, the Boösaule Montes. It is northwest of the large plume deposit of the Pele volcano. The mean height of the mountains on Io is 6,300m (20,669ft).

10. Doom Mons

Location: Titan

Height: 1,450m (4,757ft)

🚶: 3 days

Difficulty: Hard

Situated on Saturn's moon, Doom Mons is one of Titan's highest peaks and the tallest cryovolcanic mountain known in the Solar System. It could beat a climber given the snow, rain of liquid methane and ethane that might fall on it. There are also harsh winds but at least the ice-capped summit is clear.

05



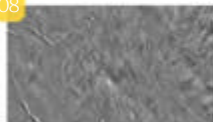
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Volcanoes of fire and ice

Volcanoes can blow hot and cold but what is the difference between the two types?

Two main types of volcano exist in space. The first and most familiar kind is the type that spews out molten rocks, typically at high temperatures of at least 700 degrees Celsius (1,292 degrees Fahrenheit).

These exist on terrestrial planets and moons that are composed primarily of metals or silicate rocks. In our Solar System they tend to be closest to the Sun. When they erupt, magma leaves the volcano and reaches the surface. It then becomes known as lava.

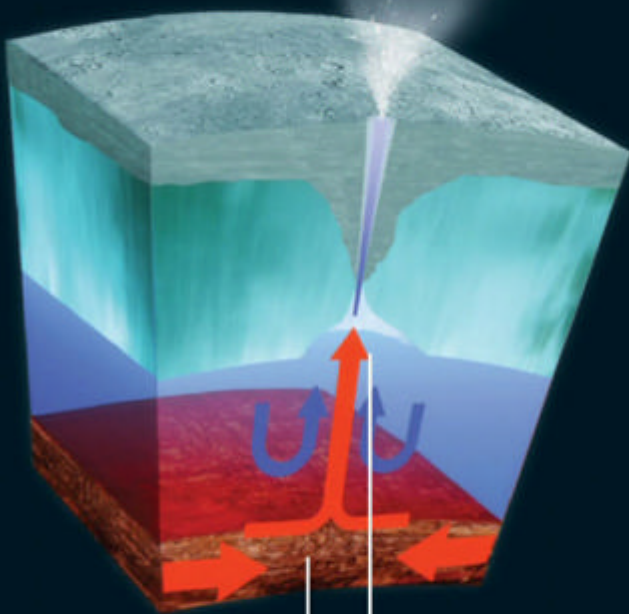
The volcanoes on Io, Venus and Mars are, or have been, of this type. Our Moon has also had such volcanism. "Recently, volcanism that was around 100 million years old was discovered on the Moon," says Dr Khan, pointing to NASA's Lunar Reconnaissance Orbiter, which showed the Moon's volcanic activity gradually slowed over time.

The second type of volcano is very different. Cryovolcanoes, which are colloquially known as ice

volcanoes, still have a heated interior but they spew water mixed with ammonia or methane rather than molten rock. Cryovolcanoes exist on the icy moons such as Enceladus and Titan, which circle Saturn.

"The water that comes up from the liquid ocean beneath the icy crust of these moons behaves very similarly to lava," says Dr Lopes. "It is defined as volcanism because it's a process of bringing material to the surface."

Cold volcanoes



Eruption

When it breaks through on Enceladus, it sends a water vapour plume and ice particles into the air. The friction heats nitrogen, which builds pressure and erupts.

The crust

Venus has a crust that is 50km (31mi) thick and it is made up of silicate rocks. Magma breaks through the crust en route to the surface.

Shield volcano

Wider than composite volcanoes, they have gentle, sloping sides and the lava is able to flow easily via vents on the volcano's surface.

Main vent

As the magma seeks to escape through a composite volcano, it moves upward, making its way through a large main vent toward the crater at the top.

Hot volcanoes

Multiple eruptions

When the volcano erupts over and over again, layers of hardened lava, tephra, pumice and volcanic ash builds up. A conical appearance appears as a result.

Tidal heating
When there is tidal friction the interior of the satellite starts to become very hot.

Melting ice

It heats a pressurised H₂O pocket that melts ices. Because the heat has to somehow escape, it begins to push upward on the body's surface.

Secondary vents

The magma also seeks other outlets and it escapes through secondary vents. Secondary cinder cones and craters are produced as the gases and fluids find their outlet.

Shield volcano

The magma chamber of the shield volcano is spread over a wider subsurface area. Shield volcanoes have a large caldera at the summit.

Lava channels

Venus has lava channels, one of which is 6,800km (4,200mi) long, greater than the longest river on Earth, the Nile. It was spotted in 1991 using the imaging radar on board the Magellan spacecraft.

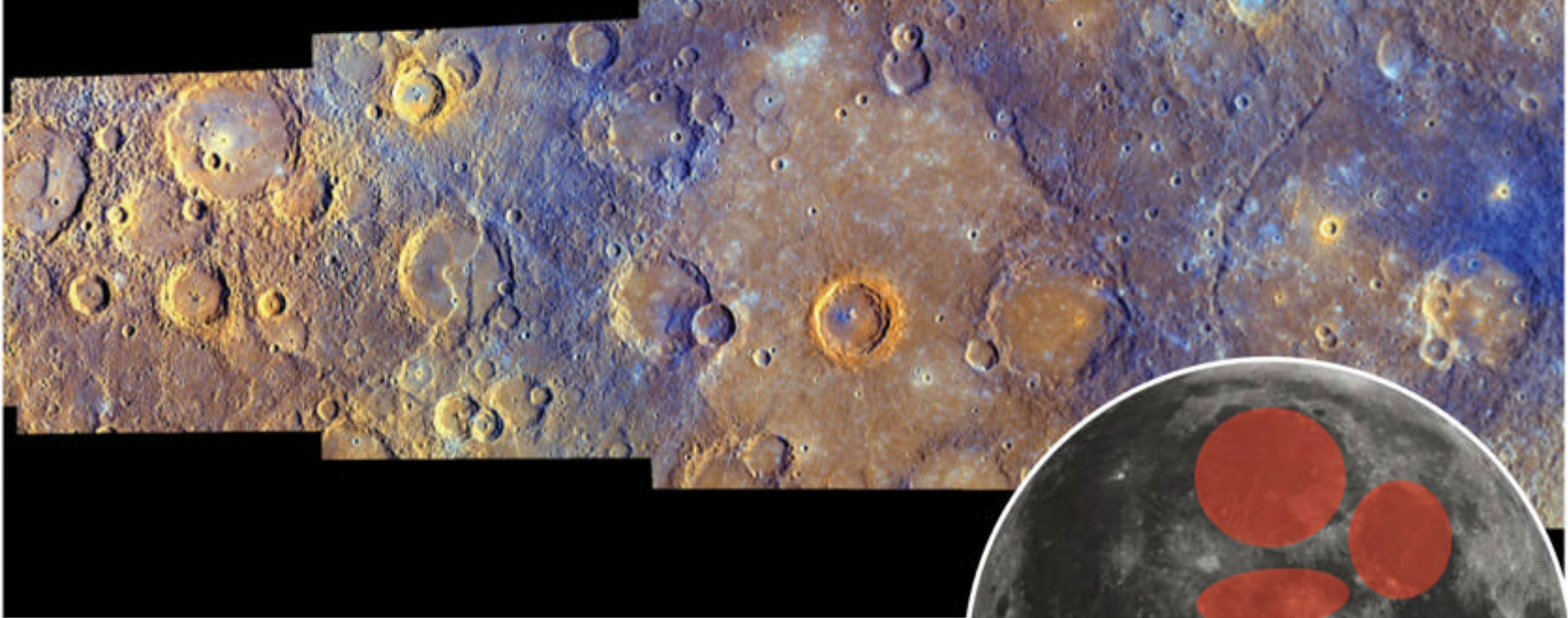
Rising magma

As the magma rises, pressure builds. The gas-pressure build up is more intense under a composite volcano than a shield volcano, which has a far less explosive eruption.

Magma chamber

Beneath the surface of a body is molten liquid rock, pooled in what is called a magma chamber. As pressure builds, the magma seeks to find a way to the surface.

The robotic space probe MESSENGER spent four years orbiting Mercury, uncovering the planet's volcanic past. Hills, vents and long channels have been photographed. One of the volcanoes was thought to have erupted for a billion years



would also cover the entirety of Germany. If it existed on Earth at that size and weight, it would break through the crust and go right to the mantle.

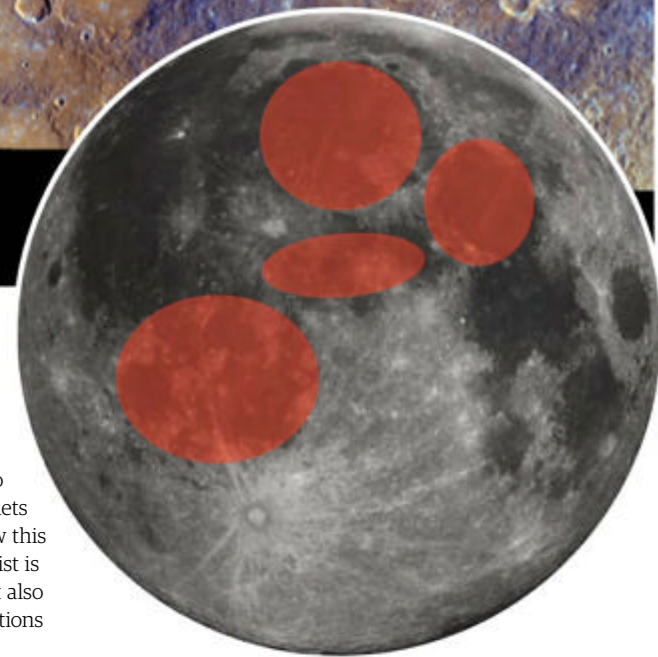
Mars also has limited plate movement, meaning the lava build up only has certain areas in which it can break through. Indeed, the surface of Mars is effectively two large tectonic plates that have been rubbing against each other. "Volcanoes are so different to each other," says Dr Lopes. "While we have instrumentation that can give us geophysical measurements and an idea of what's underneath a volcano, there is a lot that we surprisingly don't know. There may be peculiar conditions that will make volcanoes erupt in a certain way. You only have to look at Mount St Helens in Washington, which erupted in 1980. Scientists were expecting the blast to go up but it went sideways. A lot of people were not evacuated because the scientists were not modelling for it to go this way."

Mars may also have geological structures that are referred to as mud volcanoes. They are similar to the geysers in Iceland, spewing dirt from beneath the ground. A region called Acidalia Planitia in the northern plains of Mars appears to have a fair few of these and they are also found on Earth (there is a large concentration in Azerbaijan and the adjacent Caspian Sea). "It may explain the plumes of methane in the atmosphere of Mars," says Dr Khan, who notes

that the drastic differences and completely unpredictable nature of many volcanoes makes for very some very intriguing observations. "It tells us how differently planets can evolve even though they were created at the same time and relatively close to each other," he says. "If you look at the exoplanets around other millions and billions of stars, how this enormous variety of different geologies can exist is a lesson that the Solar System is teaching us. It also shows the conditions for life may exist in situations where you wouldn't think it is possible."

By way of explanation, he points to Europa, another of Jupiter's geologically active moons. Like Io, it has been deformed by tides as it orbits the planets, releasing heat through rock and ice friction. The Hubble Space Telescope revealed the moon spouting water in 2013, which showed that the hypothesis of an underground ocean was probably correct. Scientists believe nutritious material is being brought to the surface. "Volcanic vents locally heat up the water and eruptions happen," says Dr Khan. "Volcanism could be an enabler for life on Europa because it has warmth, nutritious minerals and water, which are the basic ingredients."

But just as some astronomers are looking for signs of life, so too are others keen to discover more volcanic activity on other planets and moons. Dr Lopes is hopeful that New Horizons will shed new light on Pluto where there is speculation of volcanism. It is not beyond the realms of possibility. "It's why it is important to spread your studies to other planets," she says, "because you never know



Most of the Moon is covered with hardened lava and the 'man in the Moon' is made up of old basaltic flows. Some volcanic features may be less than 50 million years old

what you may learn. Before we started studying Io, people wouldn't have imagined a moon that size could have active volcanism but it does."

Better equipment is helping enormously. "There have been a lot of advances in telescope instrumentation and techniques," says Dr Lopes. "Adaptive optics are letting us observe Io to a good resolution of 100 or 200 kilometres (62 or 124 miles) on the surface. We are getting to the point where we may have smaller and cheaper telescopes that can observe these volcanic bodies very frequently."

In order to gain a better understanding, astronomers have proposed the Kuiper mission, which will put a telescope into space with an infrared instrument. Its goals include discovering whether the plumes on Europa are driven by endogenic or exogenic processes (an action or object coming within or outside of the moon). It will also look at the effects of volcanism on Io's atmosphere and its plasma torus - the cloud that encircles it.

"We don't know if it will be funded but it would allow us to continuously observe Io," says Dr Lopes. "There are certainly things we want to know about volcanism on Io, the big mystery being the composition of the lava... studying this would help us to understand lavas from the early Earth." ■

"The conditions for life may exist in situations where you wouldn't think it is possible"

Dr Michael Khan, ESA

This bright star in Piscis Austrinus is surrounded by a complex disc of planet-forming debris, through which at least one planet follows an eccentric, 1,700-year orbit.

How rare is our Solar System?

Astronomers are fascinated by the prospect of alien planetary systems like our own – but why are they so elusive?

Up until the 1990s we were in the dark about conditions in other solar systems, simply because none had been found. Various detection efforts had failed and it seemed that planetary systems themselves might be exceptionally rare in our galaxy. Fortunately, the 1995 discovery of 51 Pegasi b, the first exoplanet around a Sun-like star, opened the floodgates. Today we know of almost 2,000 confirmed exoplanets in more than 1,200 systems.

But one thing that has caught the planet hunters by surprise is the sheer variety of the new worlds they've discovered. Less than a handful of exoplanets can be directly observed through telescopes and the vast majority are inferred only through various effects on their parent star. So working out the characteristics of these alien solar systems from the limited data available requires some ingenious mathematical tricks. Nevertheless, it has become clear that the vast majority of these unique exoplanets are very different from those closer to home.

For one thing, many planets around other stars follow orbits that are much more elliptical than the near-circles of our Solar System's own major planets. This would lead to radical changes in surface conditions and in systems with more than one planet, could even make orbits unstable and liable to shift throughout their history.

What's more, some of these planets are physically very different from anything we've previously known, including hot Jupiters (gas giants that orbit their stars in a matter of days) super Earths (rocky worlds far bigger than any in our own Solar System) and super Neptunes.

These discoveries have overturned old theories about the way in which solar systems form and

evolve. Not too long ago, experts generally assumed that if conditions around a young star were right to form a planetary system, its planets would naturally follow patterns like our own, with inner rocky planets, more distant gas and ice giants and more or less circular orbits. Now it seems that planetary systems are not only much more common, but are also more varied than previously suspected. New computer models suggest one reason for this is that planetary systems are not set in stone but change throughout their lifetime. Perhaps even our own neatly ordered Solar System is simply going through a settled phase in a complicated history.

Astronomers recognise a bias in the detection methods so far available to us, which tend to make larger, more massive planets in closer orbits easier to discover. It's only through the ongoing analysis of data from NASA's Kepler satellite that we are finally starting to get a feel for the numbers of smaller planets.

But in the search for direct analogues to our own Solar System, the nature of the central star is also important. Our own Sun is an unremarkable mid-sized yellow dwarf star, but the vast majority of stars in our galaxy are orange and red dwarfs with less mass, far less brightness and much cooler surfaces. As a result, the region around the star hospitable to the development of life lies much closer in. What's more, about one-third of known planets orbit in binary or multiple star systems.

So for the moment at least, our Solar System remains truly one of a kind, but the odds are shifting and each new wave of planetary discoveries seems to reveal systems that are more and more like our own. Given that we've studied so few of our galaxy's stars, it's inevitable that we have twins waiting to be found. ●

51 Pegasi

The first exoplanet system to be discovered around a Sun-like star has just a single known member, a hot Jupiter nicknamed Bellerophon. It orbits its star in just 101 hours and has a temperature of 1,200°C (2,192°F).

Our Solar System

Planet-hunting with Kepler

NASA's Kepler satellite has revolutionised the search for exoplanets. Prior to its launch, the main planet-hunting method had been the so-called radial velocity technique, which relied on detecting wobbles in a star's light as massive orbiting planets pull it in different directions. However, Kepler uses the transit method, looking for periodic dips in a star's brightness as a planet passes across its face. Provided a planet's orbit is aligned to Earth so that it happens to move in front of its star, transits can reveal the presence of much smaller planets. Launched in 2009, Kepler detected more than 4,000 candidate exoplanets over four years of full operation, 1,000 of which have been confirmed.



How rare is our Solar System?

Kepler-11

This Sun-like star has at least six planets circling closer than the orbit of Venus. Its planets all orbit in a plane flatter than that of our own Solar System.

PSR B1257+12

This pulsar (the burnt-out remains of a once-massive star) is surrounded by three planets in orbits of 25, 67 and 98 days. The inner planet is the smallest known, with a mass just 0.2 per cent of Earth.

HD 20782

The only confirmed planet orbiting this Sun-like star follows the most eccentric planetary orbit known, ranging between 15mn and 392mn km (9.3mn and 244mn mi) over 586 days.

Kepler-20

This system contains at least five planets, including three small gas giants and two roughly Earth-sized worlds. However, these searing planets orbit too close to their Sun-like star for life to survive.

KOI-500

This extreme system contains at least four exoplanets larger than Earth, orbiting their Sun-like star in periods of 3.1, 4.6, 7.1 and 9.5 days. An unconfirmed fifth planet may orbit in just one day.

Kepler-47

This system of at least three worlds orbiting a binary star was the first multi-planet binary discovered. The outermost planet, Kepler-47c, is a gas giant orbiting in the star's habitable zone where life might be possible.

55 Cancri

The brighter, Sun-like star of this binary star system is orbited by several huge planets – all but one closer than Venus. A red dwarf companion orbits further out.

Upsilon Andromedae

Four gas giants orbit this Sun-like primary star in this binary system, with periods ranging from 4.6 days to 10.5 years. A faint red dwarf secondary star orbits much further out in the system.

Kepler-16

This exoplanet system is home to Kepler-16b, the first confirmed planet to orbit both members of a binary star system. The Mars-sized world orbits its stars, an orange and red dwarf pair, in 229 days.

5 AMAZING FACTS ABOUT

Ceres

The Dawn spacecraft took this image of Ceres on 15 April 2015, 22,000 kilometres (14,000 miles) from its northern hemisphere



It's roughly the size of France

As far as asteroids go (or former asteroids that have since been upgraded to dwarf planets), Ceres is a whopper. With an average diameter of around 950 kilometres (590 miles), it could easily span the whole of France.

Life could actually exist here

The discovery of water on Ceres has led to speculation that life could exist on this dwarf planet. However, there are some better candidates like Mars and the moons around Jupiter and Saturn existing within the Solar System. The prospect of finding life on other planetary bodies is tantalisingly close.

Astronomers once thought Ceres was a planet

For nearly 50 years after it was discovered in January 1801, it was thought to be a new planet. This isn't surprising, given that this huge celestial object occupies a gap between Mars and Jupiter.

The surface is quite warm

...At least compared to outer space. At its relatively close proximity to the Sun, the surface of Ceres hits a high of about -38 degrees Celsius (-36 degrees Fahrenheit) and at this temperature its icy volatiles sublime into space.

It's one third of the Asteroid Belt

Ceres is easily the most massive object in the Asteroid Belt, accounting for a third of its total mass. Its rocky, icy body weighs in at a whopping 900 million, trillion tons, over three-times that of its neighbour Vesta, the next most massive object occupying the Asteroid Belt.

© NASA



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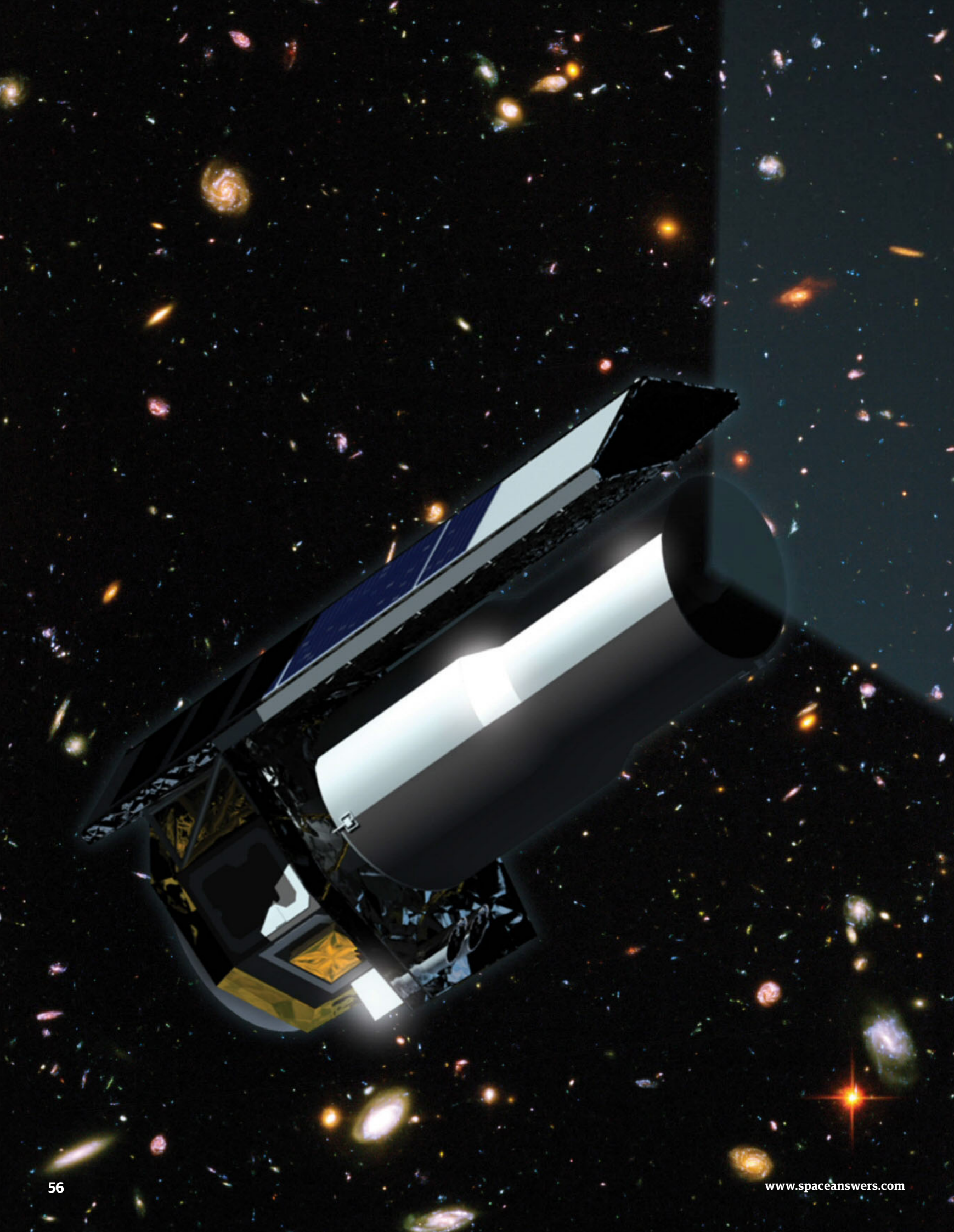


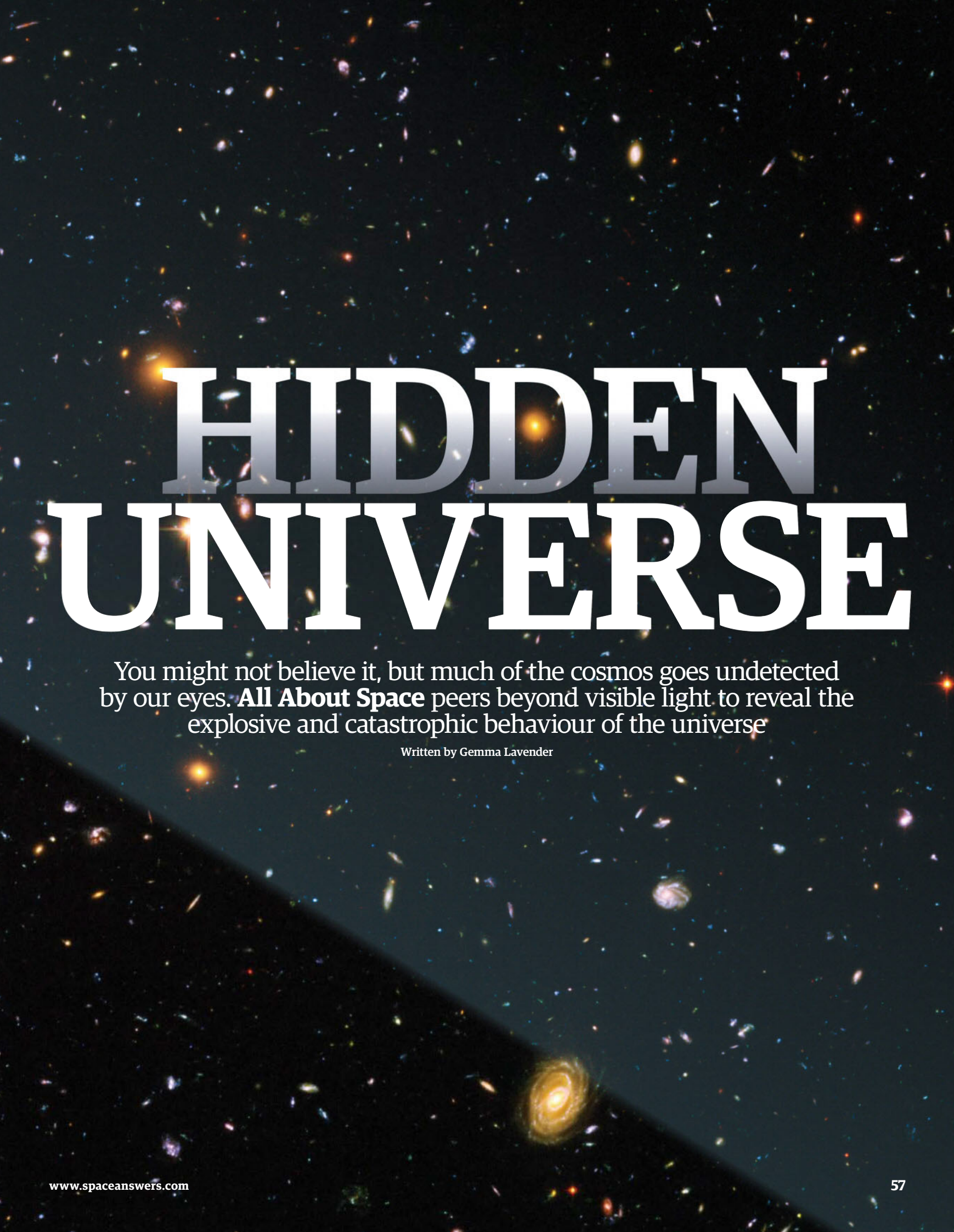
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*Well almost, model sent to 120,000 feet on weather balloon





HIDDEN UNIVERSE

You might not believe it, but much of the cosmos goes undetected by our eyes. **All About Space** peers beyond visible light to reveal the explosive and catastrophic behaviour of the universe

Written by Gemma Lavender

Hidden universe

Radio, depicted in blue, reveals an incredible amount of hydrogen in our nearest Ultraluminous Infrared Galaxy (ULIRG), Arp 220. The galaxy is the result of two galaxies merging into one. The image below shows Arp 220 as imaged by the Hubble Space Telescope



INTERVIEW

Charles Blue National Radio Astronomy Observatory (NRAO)

"Radio astronomy is utterly essential for understanding the universe, since optical telescopes only see bright stars and objects illuminated by them. Radio telescopes, on the other hand, see the cold, dark and distant universe. This includes nurseries that form stars, clouds of hydrogen gas, molecules in galaxies, energetic particles accelerated by super dense black holes and galaxies near cosmic dawn. These objects and in fact all objects in space, shine at radio wavelengths. When combined with other telescopes operating at different wavelengths, radio astronomy unlocks even more amazing information, supplying us with a more complete picture of the cosmos."

If we just relied on our eyes, we'd find that we would be blind to most of what the universe has to offer. There would be so much that we would completely miss, from the explosive nature of gamma-ray bursts, to the dusty skeletons of galaxies and even the radiation left behind by the Big Bang. This is because the universe emits light that goes well and truly beyond what our eyes alone can see. Visible light, which is the light that we see making up our everyday surroundings, is just one small part of the electromagnetic spectrum. This runs all the way from low-energy radio waves through to astonishingly high-energy gamma rays. To us, anything that's regarded as outside of the visible part of the spectrum, we just can't see. You might be surprised to learn that we produce this hidden light on Earth too. Think of infrared night vision goggles, the X-rays you might get to see a broken arm with, ultraviolet security tags or radio waves transmitting music and telephone calls across the planet. In space, these other wavelengths of light are everywhere, coming from all kinds of cosmic objects. It's like a hidden universe, but luckily for us, astronomers are

able to tune in to these other wavelengths to make the invisible visible.

Light is a funny thing, it is able to act like both a wave and a particle at the same time. This is why we say that a photon of light can have a wavelength. The longest wavelengths are radio waves, which range from a millimetre in length to many kilometres. Meanwhile, the shortest wavelengths on the electromagnetic spectrum belong to gamma rays and can be as small as just a trillionth of a metre. So to see this hidden light, astronomers need a variety of tools, from giant bowl-shaped radio dishes that can be seen from miles around, to detectors in orbit above Earth's obscuring atmosphere.

This other light remained hidden until its discovery at the beginning of the 19th century. It was the year 1800 when William Herschel used a prism to split light into a spectrum of colours and measured the temperature of each shade. He came to the conclusion that there must be an extra unseen colour beyond red because his thermometer was responding to light in the spectrum that he could not see - the infrared. A year later, the German scientist Johann

Radio

The start of radio astronomy

In the 1930s, astronomer Karl Jansky found there were radio waves coming from the Milky Way galaxy. However, even before then astronomers such as James Clerk Maxwell speculated that radio waves could be observed from astronomical sources

Revealing the radio universe

With a gathering of radio telescopes, we are able to make part of the invisible universe visible

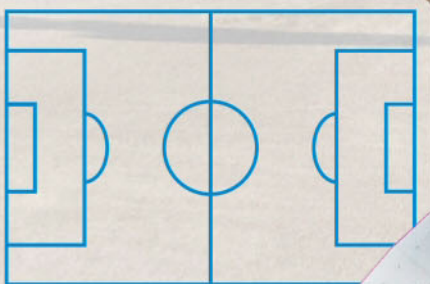
1 A very large collection
The Atacama Large Millimetre Array (ALMA) is made up of 66 dishes, all up to 12m (39ft) across and weighing in at 100 tons each. Each one of the dishes that comprise ALMA gathers faint radio waves from space.

2 Going digital
ALMA's dishes are able to turn the incoming signals from analogue into digital by converting the radio waves into binary computer code.

3 Supercomputer power
The digital data is sent along 15km (9.3mi) of optical fibres to a supercomputer whose power matches that of 3 million laptops.

4 Dished out
When astronomers around the world get the data, they are able to turn it into images that are ten-times sharper than those that are taken by NASA's Hubble Space Telescope.

A large array
Spread out across an area of 6,500m² (70,000ft²), these large radio antennas have a combined surface area about the size of a football pitch.

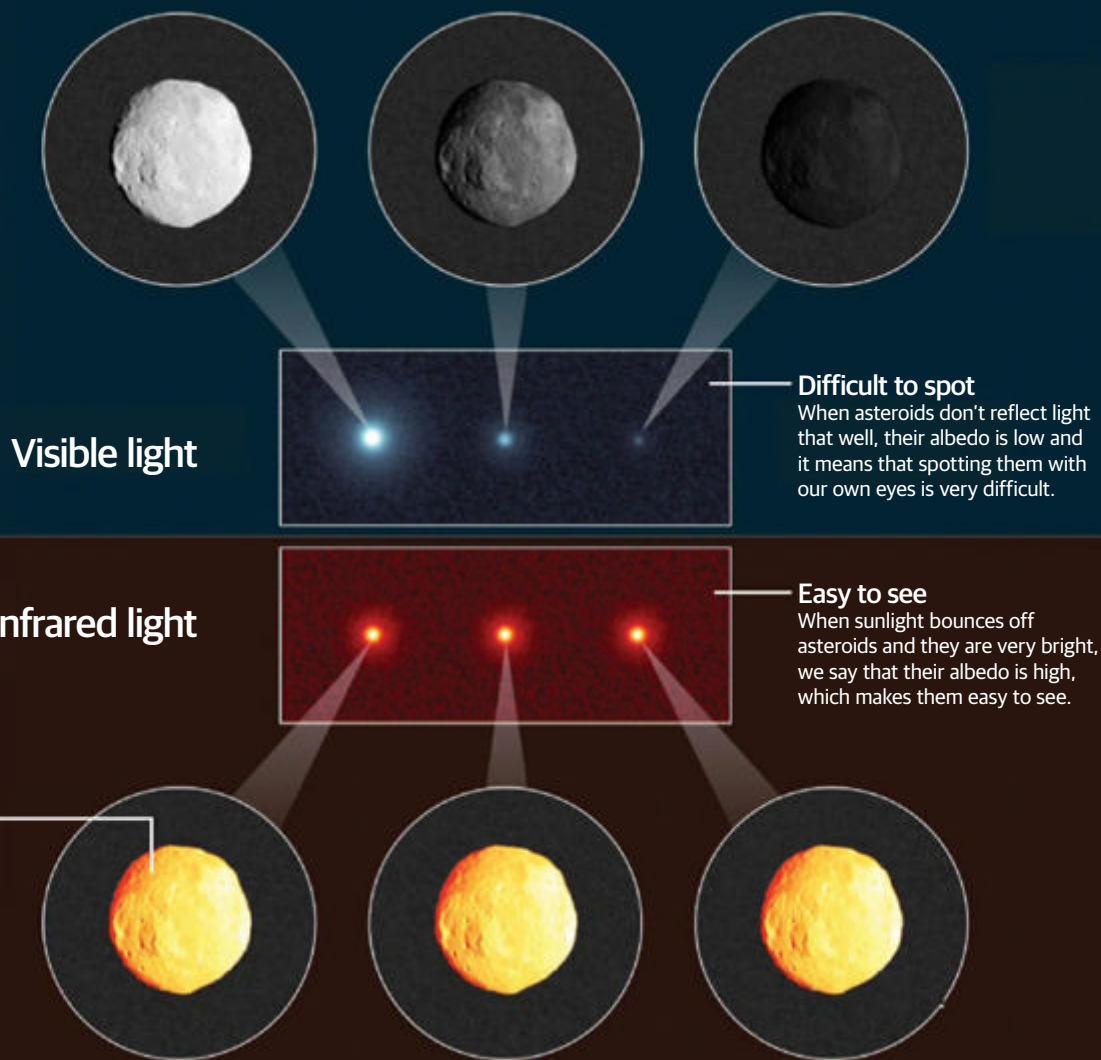


Changing the goal posts
It's possible for the dishes to be moved closer together or further away, depending on what astronomers are scouting the universe for. Vehicles capable of transporting a radio telescope weigh around 130 tons and have 28 wheels.

Microwave

A major microwave discovery
A massive turning point in astronomy came in 1965, when Arno Penzias and Robert Wilson discovered the Cosmic Microwave Background – the thermal radiation left over from the Big Bang that brought the universe into existence

Revealing hidden asteroids



Ritter conducted a similar experiment, but this time found that unseen light beyond violet had the ability to darken paper soaked with silver chloride. Ultraviolet light had been discovered.

Our planet's atmosphere doesn't want us to see some of this hidden light from the universe and it does a pretty job of absorbing infrared light using its water molecules, while its ozone layer blocks harmful ultraviolet. In fact, other than radio, microwave and infrared astronomy, most of this hidden light needs a very strong space telescope high above the atmosphere to see it. That's partly why our understanding of the universe has grown so much since the Space Age, because we can now launch telescopes far into Earth's orbit to study the mysterious hidden universe.

So let's imagine that we're able to put on infrared goggles and X-ray glasses - what can we see? Our own galaxy, the Milky Way, is a completely different beast when we look at it in other wavelengths. Galaxies, including our own, are made up of lots of hydrogen gas. Atomic hydrogen radiates at a wavelength of 21 centimetres (8.3 inches) and radio

astronomers are able to map where this atom is in our galaxy to give them an indication of the size and shape of the Milky Way, along with how fast it's actually spinning.

But there are many more things in the galaxy that spit out radio waves. There are pulsars, which are spinning dead stars discovered by astronomer Jocelyn Bell in 1967. She found a regular 'beep-beep-beep' pulse coming from these objects in the form of radio waves. These dead stars, which come from stellar explosions commonly known as supernovas, emit beams of radio waves and as they spin they flash these beams at us over and over again, creating the dramatic appearance of a pulsing object.

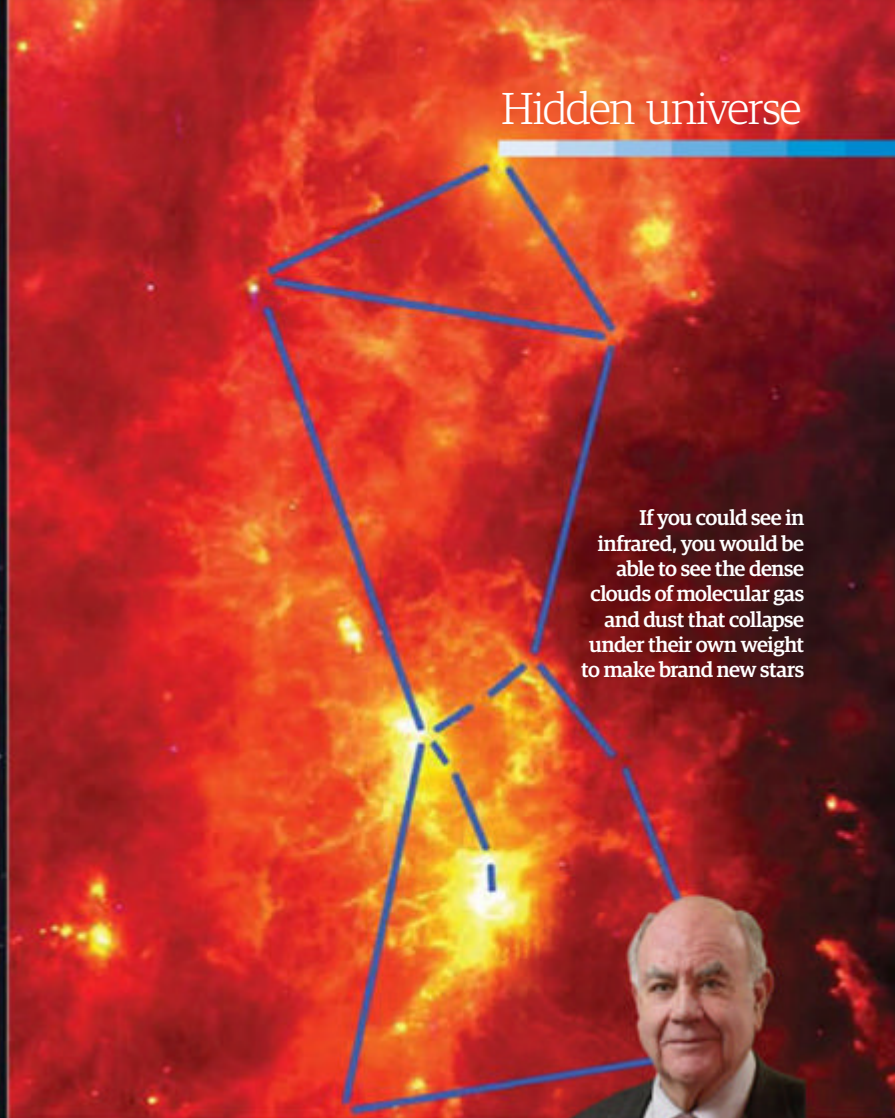
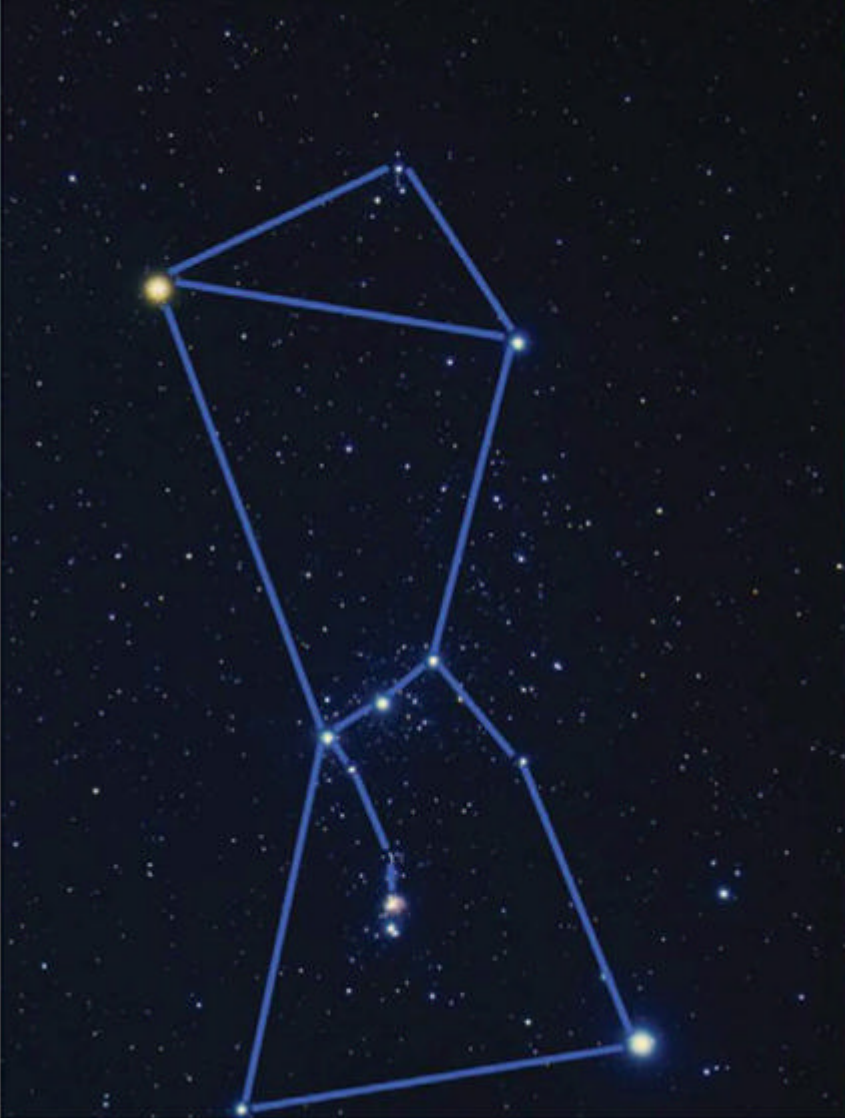
When supernovas explode, they leave behind a nebula of gas and dust blasted out by the explosion. The brightest radio objects in the sky are supernova remnants, such as the Crab Nebula, also known as M1 in the constellation Taurus. M1 is the remains of a massive star that blew itself to smithereens in the year 1054. Supernova remnants like M1 also produce radio waves, when a powerful stream of ultraviolet radiation coming from the pulsar at its heart excites the gas in the nebula and causes it to radiate in radio waves. There's more to M1 than radio though. Let's turn the dial on the electromagnetic spectrum and look at it in infrared light, which tends to come from cooler, lower energy objects. In this remnant, it is the

"Our understanding of the universe has grown so much since the Space Age, because we can now launch telescopes into orbit to study the hidden universe"

Watching star birth in infrared

Thanks to the launch of infrared space telescopes such as the Spitzer Space Telescope and the Herschel Space Observatory, we've been able to look at the birth of young stars and capture infrared light being thrown out by exoplanets known as hot Jupiters

Infrared



Hidden universe

If you could see in infrared, you would be able to see the dense clouds of molecular gas and dust that collapse under their own weight to make brand new stars

cool dust that was created in the mighty supernova explosion that we can see in infrared light. Now turn the dial again into visible light and what we see is hot gas glowing at tens of thousands of degrees. Move again past visible light and into the ultraviolet and X-ray spectrums and we see that the nebula glows at each of these wavelengths. This tells us that there is a powerful magnetic field around the pulsar in the middle. Subatomic particles, known as electrons, have an electric charge that causes them to spiral around wildly in the magnetic field. As they do so, they give off photons of energy in a process scientists call synchrotron radiation. These photons are what we see in the Crab Nebula at ultraviolet and X-ray light and wherever astronomers see synchrotron emission in the universe, they know that there must be a magnetic field lurking around somewhere.

Massive stars that explode as supernovae are found to glow brightly and possess swelteringly hot temperatures of up to 20,000 degrees Celsius (36,000 degrees Fahrenheit). Things this hot radiate in visible light but also in ultraviolet light and space telescopes such as NASA's Galaxy Evolution Explorer

(GALEX) seek out sites of massive star formation, not just in our galaxy but in other galaxies, by looking for their ultraviolet light. On the other hand, cooler stars glow best in infrared light, meaning that telescopes such as NASA's Wide-field Infrared Survey Explorer (WISE), along with their Spitzer Space Telescope, are able to sniff them out. These cool stars include the pint-sized red and brown dwarfs that can be as cool as a planet like Jupiter, or even cooler. WISE has found several brown dwarfs just a few light years away that are very dark in visible light, but are a bit brighter in infrared - at a bearable room temperature, they are found to glow quite faintly.

In case you were wondering, the Sun puts out most of its light in the visible range, but also produces infrared, X-rays, radio waves and ultraviolet too. Solar space telescopes like the Solar and Heliospheric Observatory (SOHO) and the Solar Dynamics Observatory are able to look at the Sun with cameras designed to observe in an array of wavelengths. Hot active regions on the Sun can produce lots of ultraviolet light, while the most powerful solar flares can throw out bursts of energetic X-rays. The Sun also

INTERVIEW

Giovanni Fazio

Principal investigator of the Spitzer Space Telescope

"Infrared observations have helped us to detect cold objects such as brown dwarfs and exoplanets, which are invisible at visible wavelengths. They are required to study galaxies in the very early universe. Infrared radiation can penetrate the dense dust in the interstellar medium whereas visible light cannot. This is important if we want to observe and understand the earliest stages of star formation in dense clouds of dust and gas. Interstellar dust absorbs visible and ultraviolet light and re-radiates it at infrared wavelengths. Infrared radiation can therefore be very helpful when used to map the distribution of dust in a galaxy. Infrared wavelengths are an extremely important element when it comes to searching for new life in the expanding universe."

Optical



Making a supernova remnant visible

It takes snaps in a few types of light to reveal a cosmic object in its true glory and supernova remnant, Cassiopeia A, is no exception

Hidden in visible

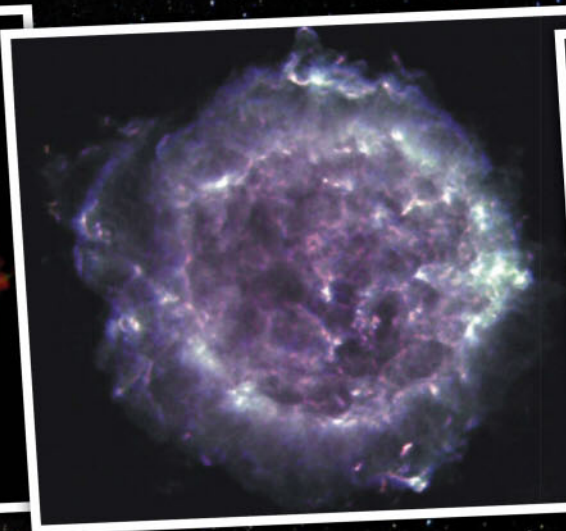
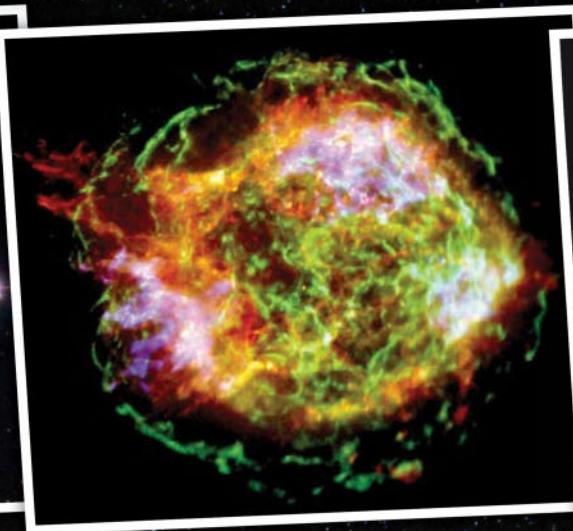
Where has Cassiopeia A gone? In this visible light image from the Hubble Space Telescope, the supernova remnant is barely visible. Here green represents glowing oxygen, red and purple are from sulphur gas and blue is light from hydrogen and nitrogen gas. The total exposure time was 2.3 days.

Getting to the heart in X-ray

This image was taken by the Chandra X-ray Observatory, which collected X-ray light for over 11.5 days. Presented in false colour, the outer ring, coloured green, is the current location of the shock wave from the supernova. Red indicates the lowest energy X-rays and blue shows the highest energy.

Revealing in radio

This radio image of Cassiopeia A was made by the Very Large Array, which is made up of 27 radio telescopes based in New Mexico. The image was made at three different frequencies: 1.4GHz, 5GHz and 8.4GHz, corresponding to wavelengths of 21.4cm (8.4in), 6cm (2.4in) and 3.5cm (1.4in).



"Gamma-ray bursts have been seen to explode from almost 13 billion light years away"

radiates at longer wavelengths, constantly blaring out in radio waves. In fact, our own star was one of the first objects to be studied with radio waves.

So far we've been kicking back with the not-so-energetic radio, but what occurs with the high-energy photons that belong to gamma rays? These come from only the most extreme objects and the first gamma-ray astronomy was done not by a dedicated space telescope, but by military satellites designed to search for gamma rays from tests of nuclear bombs during the Cold War. The satellites did detect gamma rays, but they weren't coming from nuclear bombs. Instead they were travelling from the depths of space and for a quarter of a century nobody had a clue what was causing these bursts, or even whether they were from a local source or far away. Officials

realised that if they were coming from far away, then their strength must make them the most powerful outbursts since the Big Bang.

In 1997 the mystery was solved in something of a role reversal, when scientists used the visible universe to reveal details about the hidden universe. The European BeppoSAX satellite detected the gamma rays from one of these mysterious bursts and an alert was swiftly sent out to astronomers all over the world. The William Herschel Telescope in the Canary Islands was able to point toward the scene of the burst and saw a faint afterglow of visible light from a supernova in a distant galaxy, one that lays an astonishing 6 billion light years away. This was no ordinary supernova, but the destruction of one of the most massive stars in existence as it produced a black

hole. The gamma rays are created by twin beams of high-energy particles that shoot out from the exploding star in magnetic jets, causing the electrons to spiral around the magnetic fields so strongly that they produce immensely powerful gamma rays. Since then, gamma-ray bursts have been seen to explode from almost 13 billion light years away. These bursts are the most powerful explosions in the universe and we only found them by accident!

Gamma rays don't just come from exploding stars. The Milky Way also sends out these high-energy rays. NASA's Fermi Space Telescope was designed to observe the universe in gamma rays, but what it found in the heart of our galaxy was truly amazing and surprised everyone.

Galaxies shine in light all across the electromagnetic spectrum and the dust in spiral arms is sensitive to infrared, massive star formations glow in ultraviolet and hydrogen gas emits radio waves. Although the supermassive black holes that reside at the heart of most galaxies don't emit any radiation that we can detect, their interactions with the matter surrounding them radiate at practically every

UV Hot in the ultraviolet

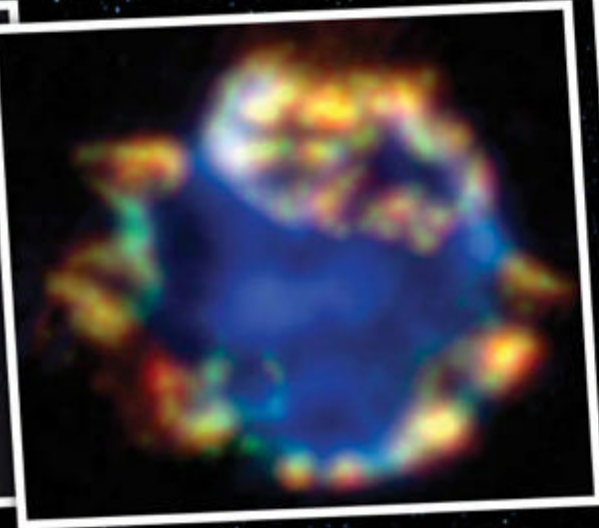
This light is thrown out by very hot objects such as stars in the early or late stages of their evolution. As we're able to capture these stars at such points in their lives, we can understand their development

X-ray Black holes burping X-rays

Astronomers discovered that when a black hole chows down on gas and dust, it'll burp out high emissions of X-rays after its meal

Collecting the infrared

This picture is the Spitzer Space Telescope's infrared view of Cassiopeia A. It too is in false colour, with different colours indicating the emission at different infrared wavelengths. Blue represents emission from silicon gas, green is argon and red is emission from dust. Yellow is where the red and green overlap.



The final picture

When all of the light is combined from several telescopes working in different parts of the electromagnetic spectrum, we get a beautiful composite image of Cassiopeia A.

wavelength possible. An active black hole, such as the monster inside the giant elliptical galaxy, Messier 87, is a powerful emitter of radio waves. It beams a jet of particles moving at nearly the speed of light that can be seen in visible light but also at other wavelengths, such as X-rays. Much quieter is the Milky Way's black hole, which is not gobbling up much gas at all. Occasionally we will see it flash in X-rays when it swallows something small like an asteroid, which is why astronomers were astonished when Fermi discovered two giant jets of particles, each pointing in opposite directions at the centre of the galaxy. These were spilling out to form bubble shapes shining in gamma rays. Each Fermi Bubble is about

25,000 light years tall and came from a dramatically violent event that happened in the centre of the galaxy several million years ago. This would have happened when the black hole consumed a large amount of gas, causing it to fiercely erupt, or during an intense period of star formation with stars so hot and massive that their stellar winds were able to blow out and heat large amounts of gas from the centre of the galaxy. These bubbles are immensely active, but are completely invisible to our eyes in the always surprising hidden universe.

But maybe the biggest thing to be seen in the hidden universe is the Big Bang itself. We cannot see the moment of formation that took place 13.8

billion years ago, but the heat energy from the Big Bang still fills the universe to this day, albeit a lot cooler than in the beginning. Today it is only -270 degrees Celsius (-454 degrees Fahrenheit) and this remnant heat energy shines brightest in microwave light. Telescopes have made maps of this Cosmic Microwave Background (CMB) radiation and from it scientists can figure out things such as how galaxies grew. Funnily enough, we wouldn't need a telescope to detect the CMB radiation because on analogue television sets, a small portion of the static comes from these microwaves.

The cold universe tends to radiate at the longer wavelengths of the electromagnetic spectrum, such as radio, microwaves and infrared. Infrared is sometimes called thermal emission, because things that are warm around us, such as our bodies or a fire, shine brightly in infrared light. Meanwhile, the most energetic action in the universe produces lots of ultraviolet, X-rays and gamma rays. It may seem like astronomers have revealed all of the universe, but there is still plenty that remains unseen. Within the hidden universe, nothing is beyond possibility. ■

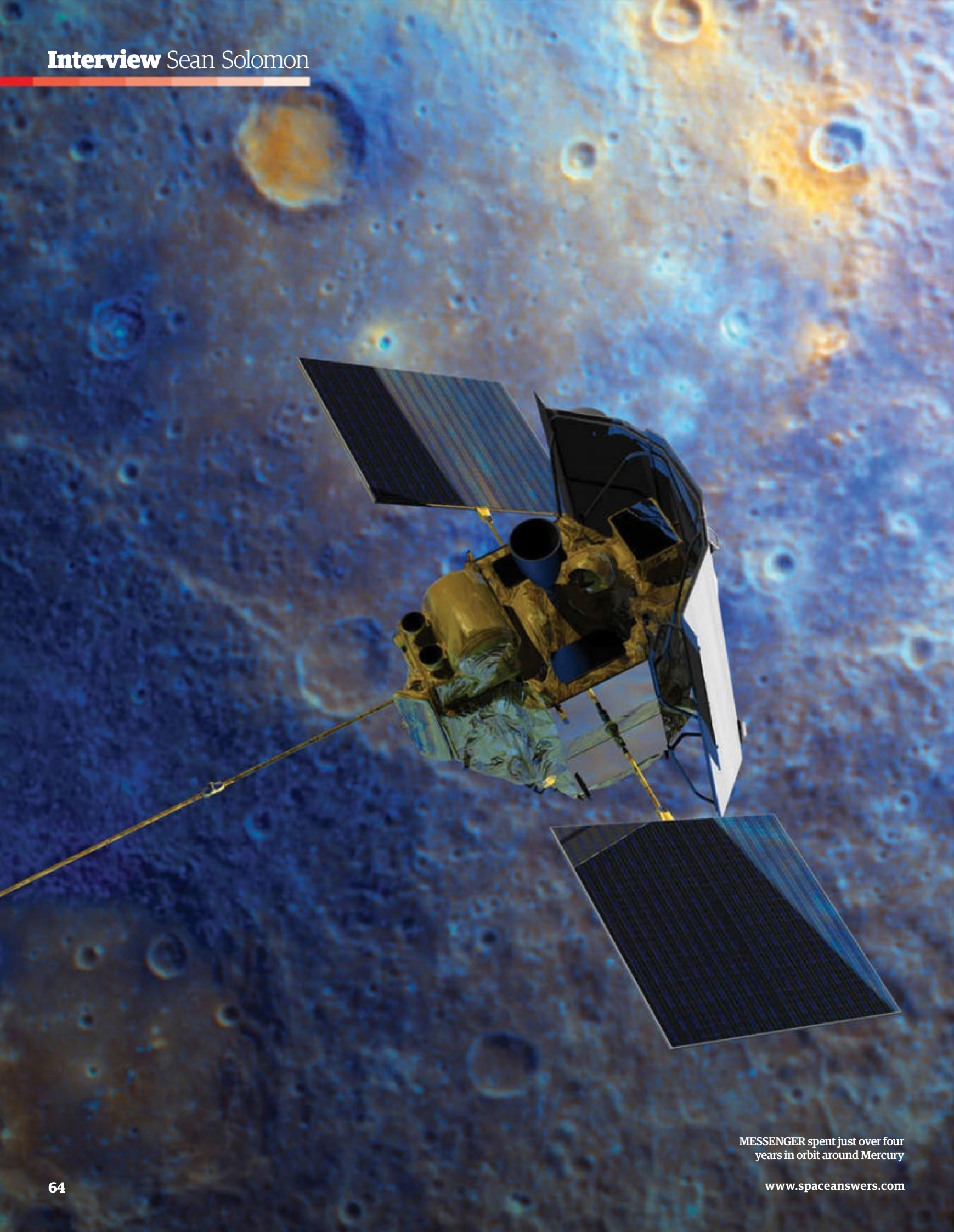
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“Fermi discovered two giant jets of particles, each pointing in opposite directions at the centre of the galaxy”

Gamma Ray

Highly energetic astronomy

There's nothing more energetic or harmful than a gamma ray. They can be found in solar flares, as well as in the catastrophic stellar explosions known as supernovae and the even more devastating hypernovae



MESSENGER spent just over four years in orbit around Mercury

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Goodbye, MESSENGER

On 30 April, the MESSENGER spacecraft ended its 11 year mission by crashing into the surface of the planet Mercury. All About Space caught up with the spacecraft's principal investigator to find out more

Interviewed by Gemma Lavender

Now that the mission is over, how do you feel?

Oh, I feel a great mix of reactions. I was at the mission operations centre (during MESSENGER's impact with Mercury), joined by many current and past members of the MESSENGER team and it was quite the celebration. Everyone was very proud to be part of a mission that accomplished a great deal more than anyone expected when we set out. It was nice to reconnect with everyone who has contributed to the mission over the years.

It has been a long process. The mission was conceived 19 years ago and selected for flight 16 years ago. It has been 11 years since the launch and more than four years in orbit around Mercury, so it has had a very nice run and the scientific results are just beginning to be distilled. MESSENGER leaves a legacy in the form of a wonderful dataset on one of our nearest planetary neighbours and we'll be trying to read the lessons from that dataset for many years.

Why was the decision made to impact the spacecraft into the planet?

[Laughs] It wasn't a decision, it was inevitable. Let me explain. To manage the thermal stress on the spacecraft, the orbit that the craft needed to follow was a very eccentric and elliptical one. During the mission, MESSENGER spent a good proportion of its time far away from Mercury and only a short time close to the surface.

The decision of an elliptical orbit was made before we launched because we knew that the mission couldn't survive a low-altitude circular orbit around Mercury. The surface temperatures on the dayside of Mercury are too high and we needed a long period away from the planet to allow enough time for the heat that MESSENGER had absorbed to radiate back into space. Since Mercury is so close to the Sun, our star's gravitational pull has a large effect on MESSENGER's orbit and the biggest effect is when the spacecraft is far from the planet.

For the last two years, the aim was to lower the spacecraft's altitude at closest approach successively between orbits. For as long as we had propellant remaining, we could do occasional orbital

correction manoeuvres that would allow us to raise MESSENGER's altitude at closest approach. Once we ran out of propellant, as we did in April, we simply had to let celestial mechanics run its course and that course was to drive the spacecraft to lower and lower altitudes until it finally crashed. So we always knew going in that we had a natural limit to the lifetime of the mission. It was set by the amount of propellant we could carry once we had completed all the burns that we needed in order to get into orbit around Mercury. But we still got four years of orbital observation for a mission that was designed to last only one year, so we think we got a lot of bonus science out of the observations. If we had the ability to carry more propellant then we would have done, so it wasn't a deliberate crash - it really was an inevitable end to the mission.

What happens when a spacecraft hits a planet like Mercury, is it similar to a meteorite impact?

It is. MESSENGER hit with a velocity of around four kilometres (2.5 miles) per second. At Mercury the typical objects that it encounters are not coming from orbit around the planet, they are coming from further away in the Solar System, so the typical impact velocity is higher. That's the main difference. A high-speed collision like that produces an impact crater and its size depends very much on the speed (the faster the object is moving, the larger the impact crater). So, rather like a small meteoroid, MESSENGER no doubt created an impact crater on the surface. We believe it is probably about 15 metres (49 feet) across and we have a fairly precise location of where that impact crater is.

We've been in regular communication with the team building the dual spacecraft mission known as BepiColombo. The European Space Agency (ESA) and the Japan Aerospace Exploration Agency (JAXA) have teamed up to put together this two-spacecraft mission that is going to be launched to Mercury in 2017. BepiColombo has a long interplanetary cruise phase before it arrives at the planet in 2024. One of the spacecraft will have a high-resolution imaging system and we'll be looking for the crater that



INTERVIEW BIO

Sean Solomon

Sean Solomon is the principal investigator of the MESSENGER spacecraft. He was awarded the Harry H. Hess Medal by the American Geophysical Union in 2005 for outstanding achievements on the evolution of Earth and other planets, and received the Distinguished Alumni Award from the California Institute of Technology in 2006. In 2014, he was awarded the National Medal of Science.

Interview Sean Solomon

The MESSENGER spacecraft being prepared for a move to a processing facility in order for its propellants to be loaded

On 30 April, the MESSENGER spacecraft beamed its very last image back to Earth before crashing into Mercury's surface



"Nine years from now when the BepiColombo mission arrives, it will be looking for a very fresh crater"

Top 5 discoveries by MESSENGER

1 Mercury has lots of water ice

Mercury has plenty of water in the form of ice despite the planet's surface temperature of 427 degrees Celsius (800 degrees Fahrenheit).

2 Mercury's volatile elements came from asteroids and comets

The elements found on Mercury's surface, such as potassium, sodium, sulphur and chlorine, are likely to have been brought to the planet by numerous comets and asteroids.

3 Mercury has shrunk in radius

Wrinkles on Mercury's surface provide evidence that the planet has shrunk in radius by around seven kilometres (4.3 miles) over the past 4.5 billion years.

4 Mercury has a magnetic field like Earth

MESSENGER confirmed the recent speculation that Mercury has a magnetic field.

5 The reason why Mercury has such an abnormally large core

It's now suspected that the planet formed in a region so hot that only iron was able to condense from a planet-making cloud known as a protoplanetary nebula.

MESSENGER created with its impact. This impact is proving scientifically interesting for the following reason: on Mercury and on other airless bodies like the Moon, the surfaces that are exposed to impacts from dust and ions darken over time and they begin to change colour. We know this because the youngest impact craters on the Moon and Mercury are brighter and differently coloured from the average terrain. Over time, the bright material exposed to space goes through some processes that we can study in the laboratory but aren't completely understood, it is these unexplored factors that cause the bright material to darken and become just like the rest of the surface. It's thought that these processes operate faster on Mercury than they do on the Moon because the velocity of objects coming from further out in the Solar System is higher, even for tiny dust particles. Additionally, the flux of energetic particles coming out of the Sun that find their way to Mercury's surface is higher than at Earth's distance from the Sun. But we really didn't have any easy way to date individual craters to test that idea up until now. In the case of the MESSENGER impact, we have a crater and we know exactly what day it was created (30 April 2015). This becomes a benchmark for future studies on how the fresh material under the surface is first exposed when the crater is formed and then darkens over time from the impact of dust and ions. So even nine years from now when the BepiColombo mission arrives, it will be looking for a very fresh crater and that will help us learn something about the rate at which darkening happens on a planet and why this phenomenon may occur more often and much faster than on the Moon.

The impact happened on the far-side of Mercury, are you disappointed that we didn't get to see it?

If we had our druthers we would have tried to design a time for that impact when it was in view of the Earth. Unfortunately we simply didn't have enough propellant onboard to keep the spacecraft high enough throughout its orbit and long enough so that the lowest part of the orbit came into view of our planet. So yes, it would have been nicer, although it still would have been challenging to see anything if there were an imaging system, telescope, or any other spacecraft. What we would have known is the very precise time when the signal stopped. The Hubble Space Telescope, as an example of a space asset, is forbidden to look at Mercury as it is too close to the Sun and the chance that the space telescope could be damaged by inadvertently looking directly at it is too high. That is the case with many sensitive telescopic instruments, so that and the fact that there isn't any other spacecraft in the vicinity probably means there wouldn't have been very much to see. We still would have liked to have known more precisely where the impact was and we could have done that by tracking the spacecraft up until the final moment - that would have given us a more precise idea of the location of the impact site.

In your opinion, what were the best results obtained from the MESSENGER spacecraft's trip to Mercury?

We had a briefing at NASA HQ a few months ago and came up with our top ten list of scientific discoveries from the MESSENGER mission. Number one was its surprising chemical composition. The

big surprise was that Mercury's powder-rocky material, the part we can see on the surface, had been predicted for many decades to be deficient in elements and compounds that are easily removed at high temperatures. The reason that prediction was made was because we've known for half a century that Mercury is very dense for its size, so it must consist of a much higher fraction of metallic iron. So the one thing we knew before any spacecraft ever went to Mercury is that it has got a very high fraction of metallic iron. The question is, how do you make a planet that is mostly iron, but is otherwise produced by the same properties that produced Earth, Mars and Venus? And so before we launched MESSENGER, there were several theories that meant that Mercury must have been made during a long period of very high temperatures. The prediction was that Mercury would be very deficient in elements that are easily removed at high temperatures, just like the Earth's Moon. These are what the chemists like to call volatile elements.

Once we started measuring what's at Mercury's surface, we realised that wasn't the case. For example, Mercury is high in sulphur, it has ten-times the abundance of sulphur of the surface of the Earth. Mercury has high abundances of sodium, potassium, alkaline metals that are easily removed at high temperatures and chlorine. Mercury has a higher chlorine abundance relative to several other elements on Earth. It is comparable to that of Mars, which is thought to be a volatile-rich planet. The finding means all the ideas explaining Mercury's high iron content are incorrect and that the inner planets must have formed in a very different way. We had to come up with a theory where it was reasonable that a planet ended up higher, in not only metallic iron, but was also able to capture and retain elements that we think of as volatile, like sulphur, sodium, potassium and chlorine. MESSENGER's discovery is really causing us to rethink how all the inner planets formed. I think that is a really fundamental result that has changed our thinking about planets.

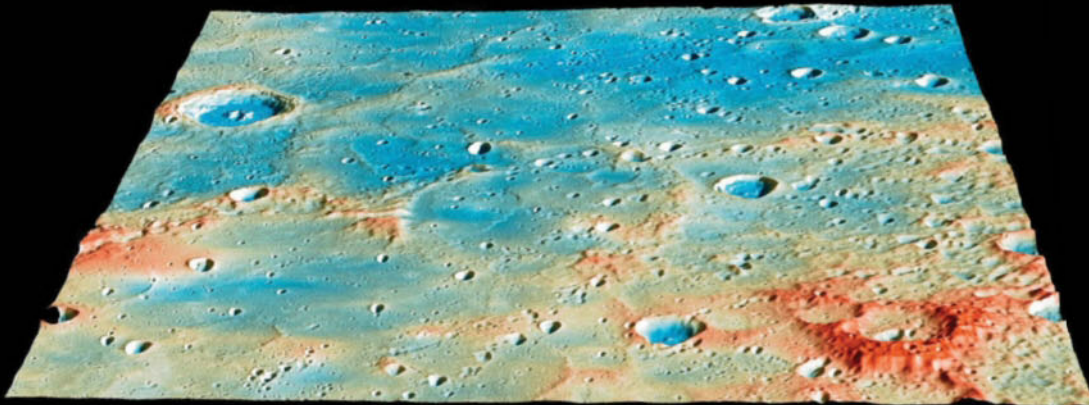
BepiColombo is a European mission to Mercury, does NASA also have any plans for a new Mercury mission?

They don't have any plans to do so, but the process of deciding what the future missions are is a long one. I think the results from the MESSENGER mission have not yet filtered down to thinking about the near-term opportunities for new missions to the planet. But we've raised enough questions with MESSENGER and I'm sure BepiColombo will raise new ones. I think interest will grow rapidly in a follow-on mission to Mercury of some kind and the question is, what kind of mission should that be? My own view is that the next logical type of mission to Mercury is a lander that can be sent to the surface, survive a landing and can withstand the tough environment at the surface. It is a long day and a long night on Mercury, the temperatures vary enormously between them and there is a high exposure to radiation, but once you're on the surface you can start to answer a lot of questions that you simply can't address in the same level of detail from orbit. I really hope there will be a lander mission in the future from either NASA or ESA. ■

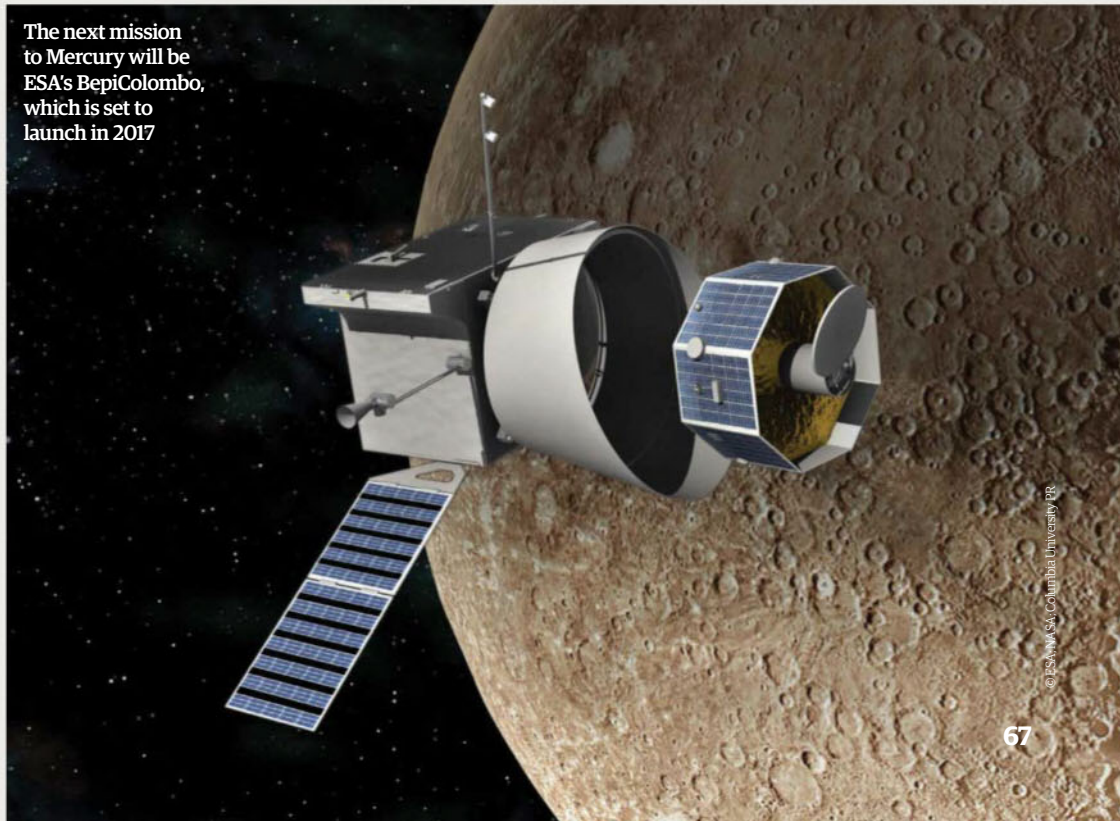


Solomon was awarded the National Medal of Science in 2014, an honour bestowed by the president of the United States

This region of Mercury now has a new crater estimated at 15m (49ft) in diameter since the MESSENGER spacecraft impacted the surface at around 4km (2.5mi) per second



The next mission to Mercury will be ESA's BepiColombo, which is set to launch in 2017

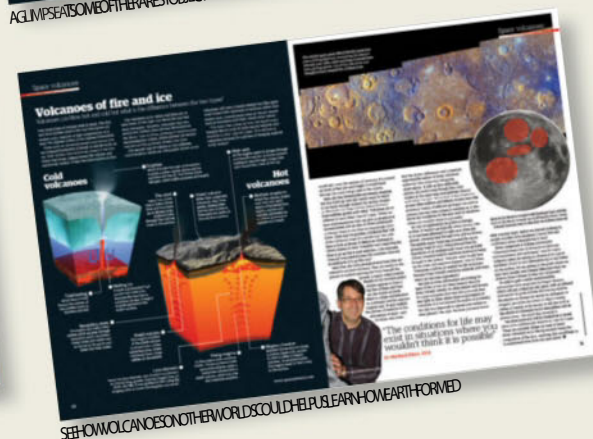


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ASTRONOMY

Why is the Moon higher in the sky during winter?

Henry Smith

The changing path of the Moon is caused by the same phenomenon that causes the Sun's path across the sky to change. The Earth has an axial tilt of 23.5 degrees, which causes the seasons and the changing path of objects in our sky. The Moon's orbit matches our path around the Sun and

does not mirror this axial tilt as such. The Moon's orbit does have a slight tilt of around five degrees, this sets up a cycle with the Earth's tilt that can see the Moon reach its widest swings north and south of the celestial equator. This occurs over an 18.6 to 19 year cycle, the last of these took place in 2005 and 2006. **JB**



SOLAR SYSTEM

Why does Venus have high atmospheric pressure?

Mark Burns

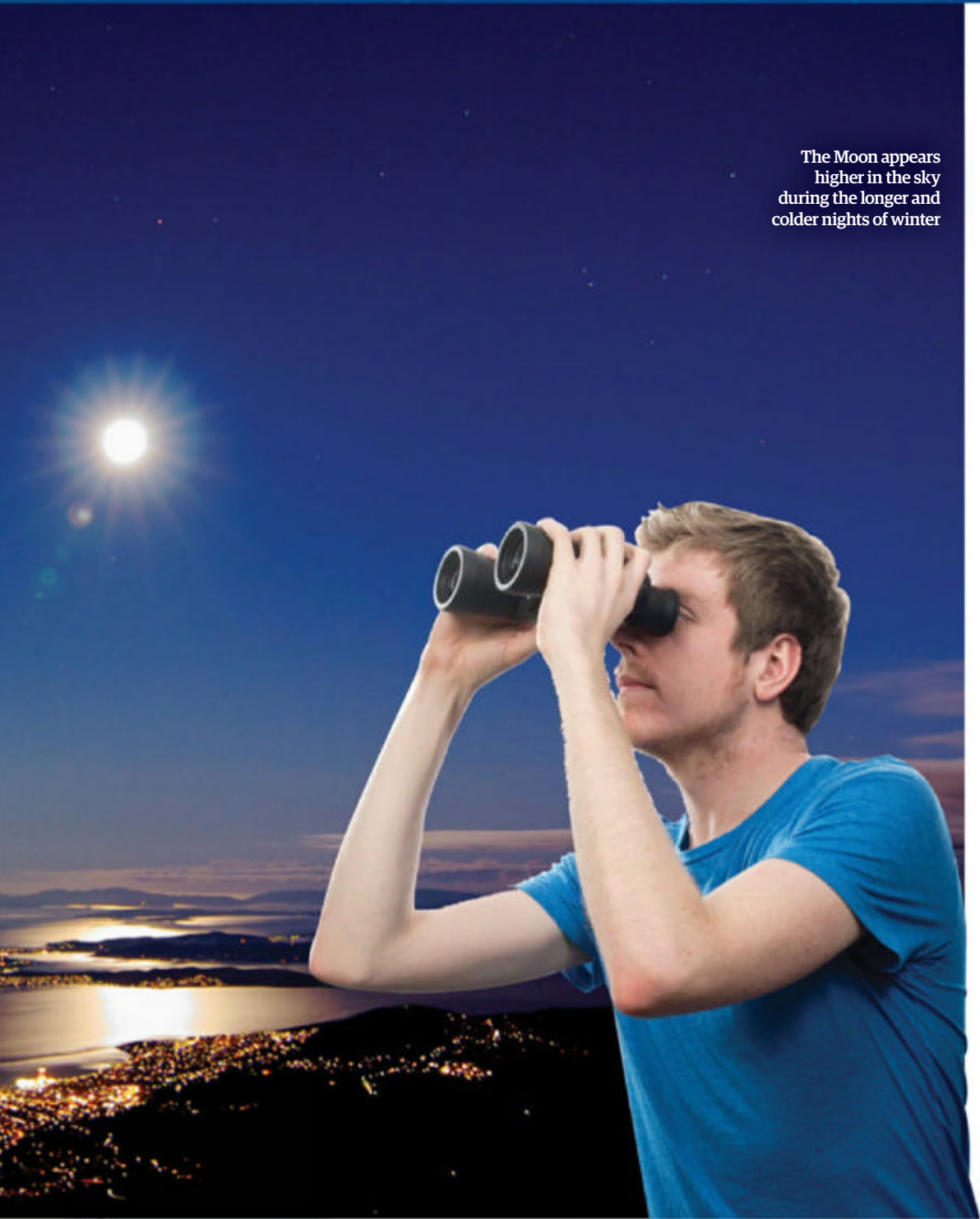
An incredibly thick atmosphere that has resulted in runaway greenhouse conditions on the planet's surface causes these hostile conditions. Of the planets we have pressure

measurements for, Venus is leaps and bounds ahead of the competition. The pressure on the surface of Venus is around 90-times greater than what we experience here on Earth. When combined with the heat of its surface,

the pressure becomes so great that the Soviet Venera probes sent to investigate the planet's surface in the 1970s and 1980s only lasted 23 minutes before they were crushed and melted by the searing heat on the surface. **ZB**

Venus has a pressure
90-times greater
than what we
experience on Earth

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The Moon appears higher in the sky during the longer and colder nights of winter



Most of the universe is not very dense at all, with only about ten atoms per cubic centimetre

DEEP SPACE

Is there sound in space?

Casey Worth

Yes there is. In particular, disturbances due to solar storms and magneto-sonic-turbulence at the Earth's magnetopause - the boundary between the planet's magnetic field and the solar wind - make enormous acoustic wavelengths. However, we're unable to hear this sound. This is because these disturbances are not travelling through the gases that are needed to turn them into the pressure waves that our ears can pick up, just like the air that they travel through here on Earth. Space isn't very dense at all, with only around ten atoms per cubic centimetre, so in order to detect cosmic pressure waves, we need to detect them with technology. **GL**

SPACE EXPLORATION

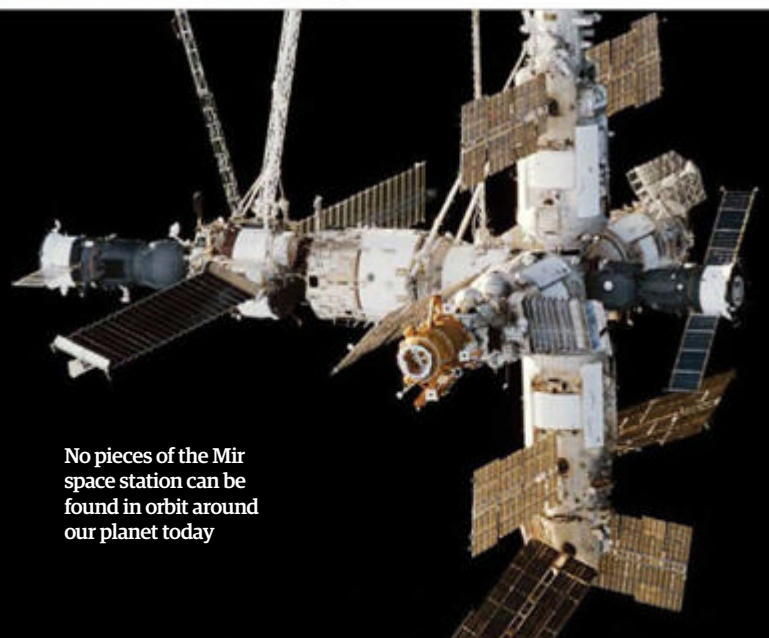
Are there still pieces of the Mir space station in orbit around Earth?

Fiona Cooper

The Mir space station was successfully de-orbited in its entirety in 2001. No pieces were left in orbit and the decision to bring it down while still operational was to make sure that it wouldn't fall at a later time in an uncontrolled manner.

The reason for the concern was built on the fact that Mir was the largest spacecraft to be destroyed through controlled re-entry. There were a few

worries that some of the larger pieces may survive the trip, potentially causing damage. To reduce this, Mir's entry path was plotted so that it would carry the station over the Pacific Ocean and away from areas with a human population. The de-orbit went as planned with the debris falling into the ocean. However, this did not stop some sneaky and intrepid salvage hunters from collecting a few sizeable pieces of the wreckage. **SA**



No pieces of the Mir space station can be found in orbit around our planet today

Sending both humans and spacecraft into space provides information that will help us to one day send people to Mars and beyond



SPACE EXPLORATION

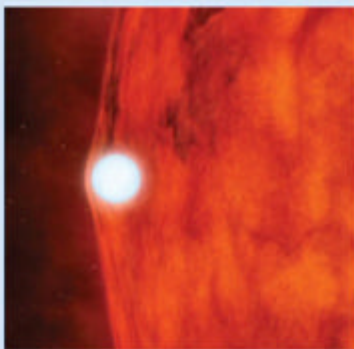
DEEP SPACE

What is a Thorne-Zytkow Object?

Adam Turner

A Thorne-Zytkow Object (ZWO), also known as a hybrid star, is a strange object where one star is packed inside the shell of a larger one. It's thought that one of these objects is made when a dense, small and dead star, such as a neutron star is swallowed by a larger dying red giant.

Physicist Kip Thorne and astronomer Anna Zytkow first proposed the existence of Thorne-Zytkow objects in 1975. Amazingly, the very first candidate for a hybrid star named HV 2112 was discovered only recently in 2014 in the Small Magellanic Cloud (SMC), which rests around 199,000 light years away. **GL**



A hybrid star, also known as a Thorne-Zytkow Object, was discovered around 40 years after these objects were first proposed

Why send people into space when a robotic spacecraft costs less?

Joe Bradley

Robots, such as the Curiosity rover, are very beneficial for missions that require precise and repetitive measurements or manoeuvres, as well as missions that last a considerable amount of time. Humans, on the other hand, are much better suited to tasks involving

decision-making, or those that require constant adjustments and intervention from scientists.

Sending both spacecraft and humans into space is a worthwhile endeavour since we can learn a great deal of information from both, which can later help us in our goal to send

people beyond Earth. By sending humans into space we can gain unique insights into the workings of the human body, especially the parts that are masked by gravity here on Earth, something that we've learned more about from astronauts living aboard the International Space Station (ISS). **GL**

DEEP SPACE

Which planets inside and outside of our Solar System were the last to be discovered from Earth?

Emmett Connell

Following Pluto's demotion to dwarf planet, the last planet in our Solar System to be discovered from Earth was Neptune in 1846. However, the last exoplanet discovered using ground-based telescopes came at the end of March. Recently, new data

from the National Optical Astronomy Observatory (NOAO), Subaru and Keck telescopes has highlighted five new planets orbiting three different stars.

New exoplanets are found regularly with the total approaching 2,000. After studying data from surveys done on exoplanets we are now of

the belief that planets are a fairly common occurrence around stars. This revelation has led to speculation on the possible presence of life in the universe. While some of these planets share similar characteristics with our own, further extensive research needs to be done. **SA**



Ground-based telescopes, such as those at the National Optical Astronomy Observatory (NOAO), have helped us to uncover alien worlds from Earth

Questions to... @spaceanswers f /AllAboutSpaceMagazine @ questions@spaceanswers.com

Quick-fire questions

@spaceanswers

What is it that makes black holes glow?

Gravity pulls material such as gas and dust into a black hole. The molecules making up this material swirl around so fast that they heat up and throw out X-rays that are detected as a soft glow.

What are the brightest objects in the universe?

Shining anywhere from ten to 10,000-times brighter than the Milky Way, quasars can be found at the very centres of galaxies with supermassive black holes at their hearts.

What's the biggest moon in our Solar System?

Jupiter's moon Ganymede is the largest moon in the Solar System with a diameter of 5,268 kilometres (3,270 miles).

How fast can hypervelocity stars really move?

Gaining their speed by being thrown out of their host galaxy, hypervelocity stars can reach whopping speeds of up to 3.2mn km/h (2mn mph).

Who is the oldest person to enter space?

The first American to orbit Earth in 1962, John Glenn, made space history once again in 1998 when he became the oldest person to travel into space at the age of 77.

Are the James Webb Space Telescope's mirrors actually made of gold?

The space telescope's mirror is divided into 18 hexagonal-shaped pieces. These are not made entirely of gold, rather they are coated in the metal.

How heavy are white dwarf stars?

These dead stars have a mass comparable to the Sun. That's around 330-times greater than the mass of Earth.



Saturn would cause chaos on our planet if it swept past us

SOLAR SYSTEM

What would happen if Saturn moved past Earth?

Justine Hamilton

With a phenomenal mass nearly 100-times greater than our planet, Saturn has an amazingly strong gravitational attraction. However, when it really comes down to it, both planets would cause complete and utter chaos on each other.

Some time before Saturn reaches our planet, the Moon would get thrown out of its orbit, since the ringed giant would have much more of an influence on our lunar companion than the Earth. In response, our planet's gravity would completely disorientate Saturn's rings, which we

know to be made up of ice, dust and rock, by pulling them in toward it.

As Saturn gets closer, say at a distance similar to the Moon, disaster on Earth would be on a global scale with floods and huge tidal waves. Earth would subsequently get torn apart by strong tidal forces. **GL**

DEEP SPACE

What's the heaviest star cluster?

Libby Coleman

The largest globular star cluster in the galaxy is Omega Centauri, which contains the mass of 5 million Suns. Omega Centauri actually stands head and shoulders above other globular clusters, being around ten-times more massive than the typical size of these objects.

Another quirk is that this particular cluster has a varied population of stars. This combination of facts has led scientists to believe that Omega Centauri could in fact be the remnant of a smaller galaxy consumed by the Milky Way in the past. Omega Centauri is usually tricky to spot from the northern hemisphere, but we are approaching our best opportunity to spot it. During May it will be due south at around 11pm (UT) and should be visible to the naked eye. **JB**



Star-packed globular cluster, Omega Centauri, is a hefty star cluster with a mass of 5 million Suns

Quick-fire questions

@spaceanswers

What exactly is a reflection nebula?

A reflection nebula is a cloud of gas and dust that doesn't make its own light as it's too thick for the bright stars to shine through.

Where do most meteorites fall on Earth?

Earth is comprised mostly of oceans, so the majority of meteorites fall into the sea.

How many constellations are in the southern hemisphere?

There are 32 major constellations in the night sky over the Earth's southern hemisphere.

Is it possible for our Sun to become a black hole?

No, it isn't possible because our star is too small. Stars have to be at least 20-times more massive than our Sun to become one.

How and when did Earth get its name?

The name Earth simply means the ground and comes from Old English and German languages. Our planet's name is at least 1,000 years old.

How many galaxies are in the universe?

While the exact number is not known, it's thought that there are at least several billion galaxies in the cosmos.

How long did Sputnik 1 stay in space?

Sputnik 1, the first artificial Earth satellite, spent a total of three months in space.

Can moons have rings?

It is possible for a moon to have rings. An example of this is the Saturnian moon Rhea, which is thought to have a tenuous three-ring system.



SPACE EXPLORATION

What happens if an astronaut becomes ill in space?

If an astronaut becomes very ill they must return to Earth

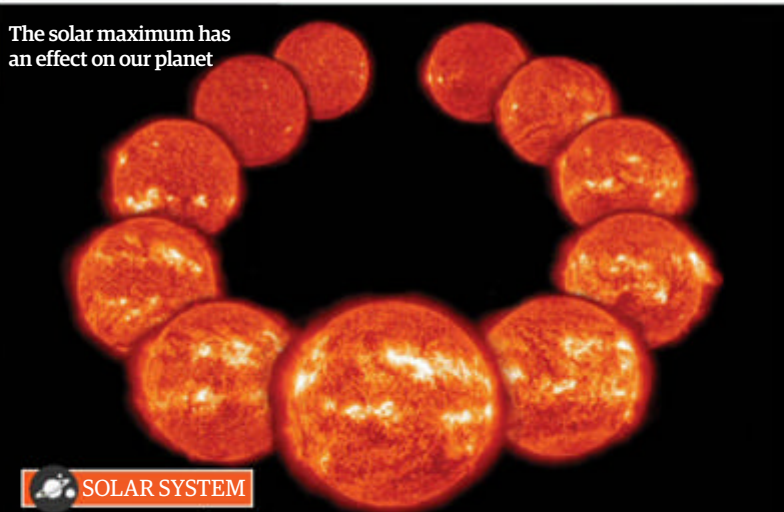
Stephen Fuchs

To cover this potentially dangerous situation, at least one member of the crew is trained as the crew medical officer. In the case of a medical emergency they would take charge to ensure the best course of action was taken.

On top of normal first aid training, the medical officer is also prepared for several more serious injuries. They are

trained and equipped to stitch wounds, give injections and perform emergency resuscitations. To facilitate this, the spacecraft is fitted with medical kits that can be used to carry out treatments. The kits can also be used to stabilise a patient for the flight back to Earth. In the case of an injury or illness the ISS has two escape pods attached. These are two vessels that would rapidly return to Earth. **JB**

The solar maximum has an effect on our planet



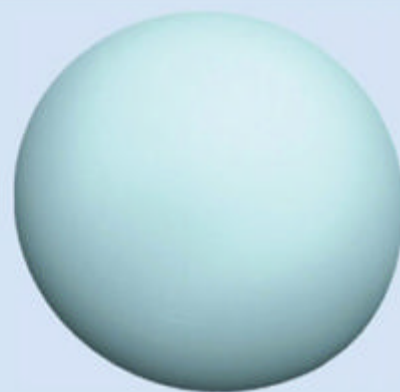
SOLAR SYSTEM

Does the solar maximum have any effect on Earth?

Timothy Davies

The solar maximum is the crescendo of the Sun's 11-year activity cycle and it can have an effect on us on Earth. During solar maximums we see a huge rise in the number of sunspots, prominences (large gaseous features extending outward from the surface) and solar storms. As all of these are a result of magnetic outbursts, they can have an effect on our planet's communication systems.

Solar storms in particular present a large threat as these events eject a huge amount of electromagnetic and particle radiation. If pointed toward the Earth, the radiation produced by these storms can disrupt radio communications, electrical power systems and damage satellites. Luckily the space around Earth and the planet itself is protected from a lot of this thanks to our magnetic shield called the magnetosphere. **ZB**



In order to survive the harsh environment of Uranus, life would have to be extremely different to how we know it

SOLAR SYSTEM

What would life be like on Uranus?

Shaun Allan

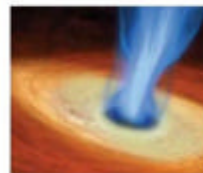
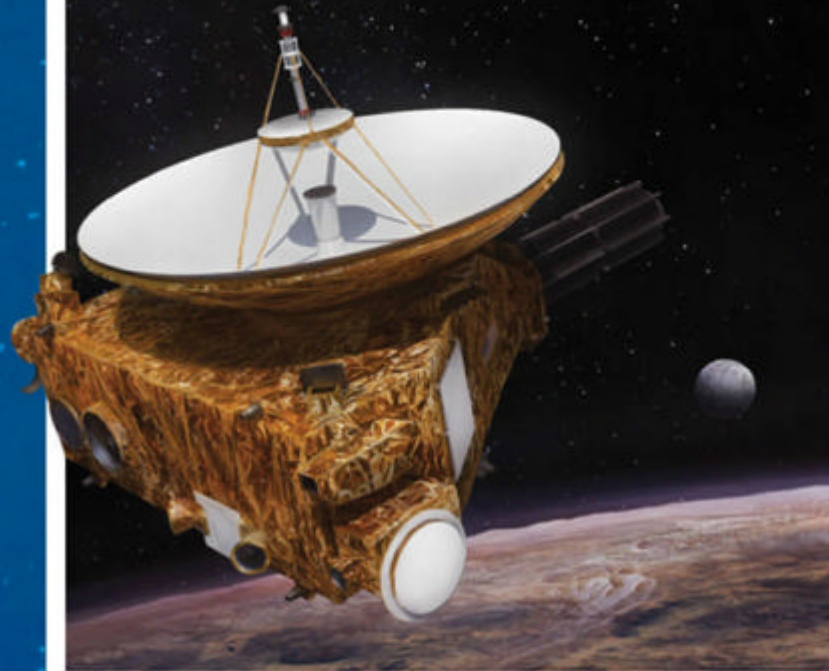
If life did exist on ice giant Uranus, it wouldn't be the life that we're used to. The fact that this giant planet is made mostly of ices, has no solid surface and has an atmosphere with a freezing temperature of -224 degrees Celsius (-371 degrees Fahrenheit), along with a core heated up to 4,700 degrees Celsius (8,492 degrees Fahrenheit), makes it a very inhospitable place to live for any complex life.

It's very unlikely that life exists on Uranus. Not only because of the aforementioned characteristics of this planet, but also because of the intense pressures that would crush life. In addition, it has been noted that there's no process to supply organisms with energy. **GL**

Next Issue

PLUTO: OUR LAST FRONTIER

Our closest ever look at the dwarf planet as New Horizons makes space history



BLACK HOLES & TIME TRAVEL

A beginner's guide to space-time and Einstein's universe



10 OUT OF THIS WORLD RESCUES

Apollo 13 and missions brought back from the brink of disaster



GALACTIC POWER

Discover the supermassive centres of the brightest galaxies in space



CAROLYN PORCO
GALACTIC FUEL TANKERS
DAYTIME ASTRONOMY
COSMIC EXCLAMATION MARK
WHAT'S THAT SPACE ROCK?
MISSION PROFILE: CURIOSITY ROVER

In orbit
25 Jun 2015

ASTRONOMY

Why can't I see the Milky Way during spring?

Geraint Ray

During the spring, the Milky Way appears to run along the horizon and is blocked out by a much denser atmosphere near the ground, making it very difficult to see its dusty trail. Even under dark and clear skies, you would still find it hard to pick out our galaxy in the northern hemisphere.

The best time to see the Milky Way is during late summer through to early autumn

The best time to catch the stunning Milky Way is during late summer and the period leading up to early autumn. During this time our galaxy's brightest portions can be found running from the south-west sky through to the north-eastern parts. You should also be able to identify a beautiful arch spanning overhead. **GL**

DEEP SPACE

Why do we see some galaxies edge-on and others face-on?

Sam Maise

When the universe formed, it did so following a fairly loose structure. This difference in galaxy shape simply arises from their orientation with respect to the Earth.

Our current understanding of cosmology suggests that dark matter helped shape the large-scale structure of the universe. However, the finer details such as the orientation of galaxies and similar objects were left to form freely. As a result we don't see any particular alignment or facing of these objects, giving us a varied view of what is around us. This view proves to be invaluable for researchers, as different perspectives can reveal different information regarding the mechanics of galaxies. **SA**

Face-on and edge-on galaxies can be found in the universe



STARGAZER

GUIDES AND ADVICE TO GET STARTED IN AMATEUR ASTRONOMY

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The latest essential astronomy gear and telescopes reviewed

Venus is one of the brightest objects in our night sky

Jargon buster

Greatest elongation

The point at which Venus is furthest from the line between the Sun and Earth, appearing about 45 degrees from the Sun.

Inferior conjunction

The point at which Venus and Earth are closest together and both lie in a direct line with the Sun.

Heliocentric

This is the astronomical model in which the Sun is at the centre of the Solar System and orbited by all the other planets.

Geocentric

This is the idea that the Earth is at the centre of the Solar System and is orbited by the Sun and all other celestial bodies.



Observer's guide to Venus

Over the coming months you'll have the chance to see Venus's famous phases

In room 55 of the world famous British Museum in London lies the tablet of Ammisaduqa. About the same size as a paperback book and made of clay, it dates from the 7th century and was created in the northern Iraqi city of Nineveh. Its ancient surface is littered with engravings in cuneiform - one of the oldest forms of writing - and charts observations of the planet Venus from 1,000 years earlier. Made over two millennia before the invention of the telescope, it shows that the planet is easy to spot and has been observed by our ancestors for countless generations. And just as it has been doing for thousands of years, Venus is currently putting on a show in our modern skies. Make sure you don't miss your chance to take a look at this spectacular sight.

Being the closest planet to us, it is no surprise that Venus is such an easy target to find in the sky. The only thing you can possibly mistake it for is the light of an unmoving aeroplane. However, that doesn't tell the whole story and due to its highly reflective atmosphere, Venus is considerably brighter than it should be, only outshone by the Sun and the Moon. The planet is enveloped in clouds of sweltering carbon dioxide and laced with sulphuric acid that traps in a lot of the heat it receives from the Sun. With temperatures often tipping 460 degrees Celsius (860 degrees Fahrenheit), this runaway greenhouse effect makes Venus the hottest planet in the Solar System even though it doesn't lie closest to the Sun.

The downside of this scorching world, from our point of view, is that it makes the planet harder to explore at close quarters. Missions like NASA's Magellan probe had to use radars to peer through the thick cloud decks and map the planet's mysterious and interesting surface. They found many more volcanoes than on Earth, along with an abundance of thunder, lightning and tectonic activity. When the ten Soviet Venera probes descended down to the Venusian surface, they didn't last more than two hours. In some cases they perished in less than half an hour, completely baked by the heat, dissolved in the acid and buckled under an atmospheric pressure almost 100-times greater than our own.





STARGAZER

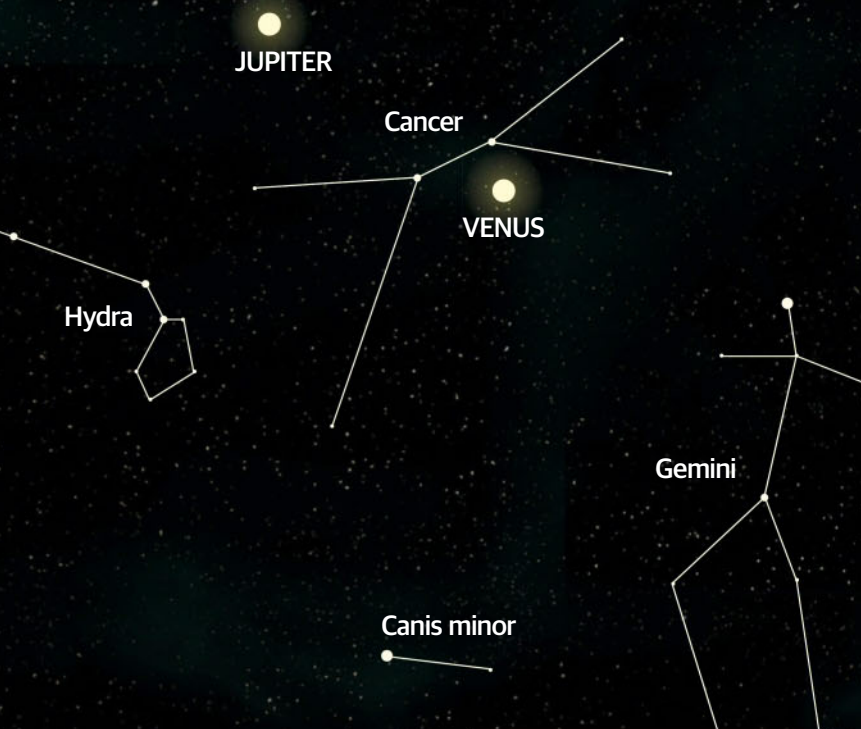
Leo minor

Leo

Lynx

The phases of Venus

From now until August, Venus will gradually wane from half illuminated to a tiny crescent



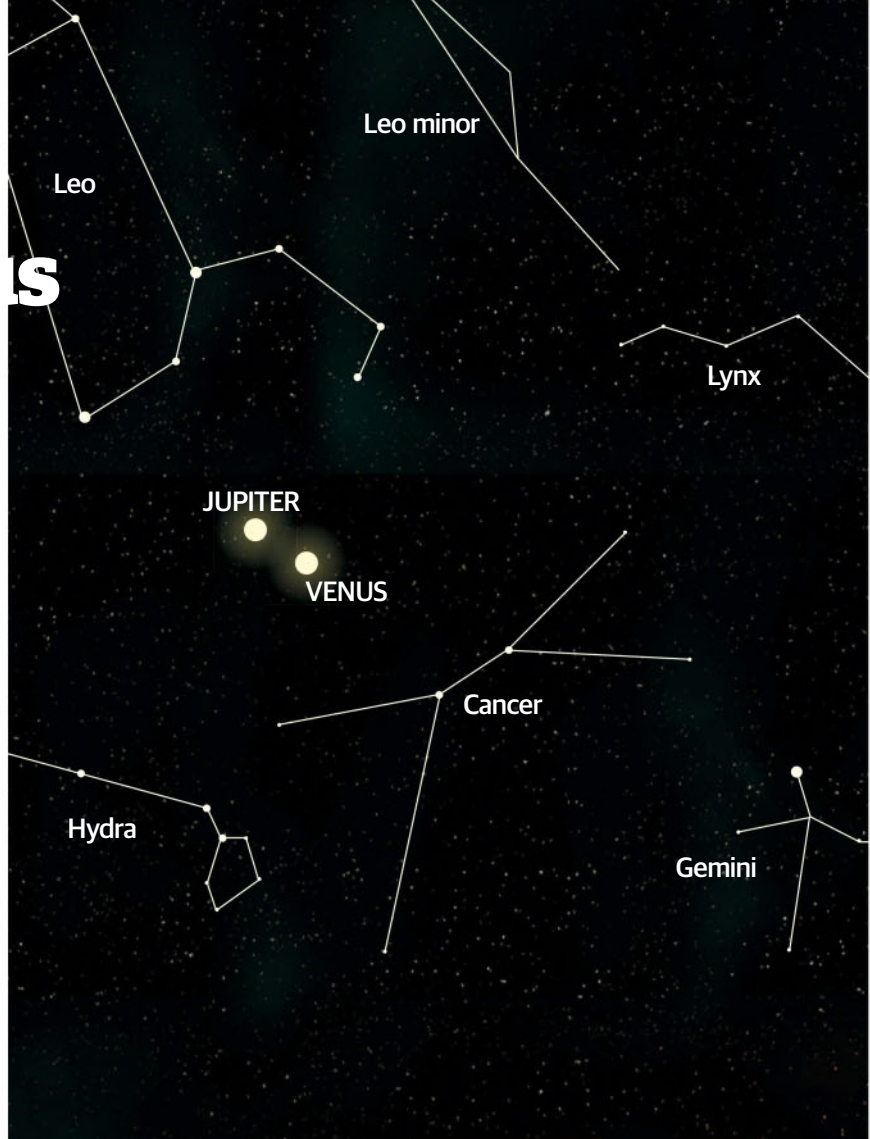
Date: 11 June 2015
Phase: 48%
Constellation: Cancer
Magnitude: -3.97
Minimum optical aid: Unaided eye



Yet the probe's loss is our gain. Those same clouds reflect 70 per cent of the sunlight that falls on them, significantly boosting the planet's brightness in our sky and allowing civilisations like those in ancient Iraq to track its motion across the heavens. It is 15-times brighter than any star in the night sky. Although not a star itself, it has long been known as the 'morning star' or 'evening star'. However, Venus's unique appearance differs in one striking way from a star - it doesn't twinkle. Stars twinkle thanks to our own atmosphere. They are so far away from us that we can only ever see them as tiny pinpricks of light. If a pocket of atmospheric dust and gas moves in front of that light it can temporarily block it out entirely, meaning that from our perspective the stars seem to flicker on and off. Planets, however, are so much closer to us in the Solar System that they

actually appear as discs in the sky whose light can never be blocked out entirely.

If you have a pair of binoculars it is well worth pointing them toward Venus to see that disc up close. As always with binoculars, setting them up on a photographic tripod will give you a more stable view than the wobbling caused by holding them by hand. From now through to August you should easily make out one of the most famous sights in astronomy: the phases of Venus. As it orbits closer to the Sun than we do, the amount of light Venus reflects toward us changes, in this sense it is similar to the phases of the Moon. When the planet lies far from the line between the Sun and Earth we see phases akin to a first-quarter and last-quarter Moon, with the planet half illuminated. This point, known as greatest elongation, happens twice in Venus's 225-



Date: 25 June 2015
Phase: 38%
Constellation: Cancer
Magnitude: -4.11
Minimum optical aid: Unaided eye



day orbit. Venus will be at greatest elongation east in the early hours of Sunday 9 June. Around this point the planet will appear about 45 degrees away from the Sun in the sky and will be approximately 50 per cent illuminated.

Over the coming months Venus will slowly head for an inferior conjunction - the point at which it sits between Earth and the Sun. This will happen on Saturday 15 August and it will mean Venus disappears from our sky, lost in the glare of the Sun. However, its journey toward this point makes for spectacular viewing. Its phase will gradually decrease until it reaches the faintest sliver of a crescent. However, despite its waning phase, Venus will continue to get brighter for a time as it gets closer to us. It will be at its most dazzling on 10 July.

By observing the phases of Venus you will be following in a long line of astronomical greats, most notably Galileo Galilei. The Italian was the first person to see the changing shapes of Venus in the early 17th century, immediately realising it vindicated Copernicus's heliocentric idea that the Earth orbited the Sun and not the other way around. Only if both Earth and Venus were circling the Sun, with Venus

"Venus's unique appearance differs in one striking way from a star - it doesn't twinkle"

STARGAZER Observer's guide to Venus



Date: 9 July
Phase: 27%
Constellation: Leo
Magnitude: -4.18
Minimum optical aid: Unaided eye



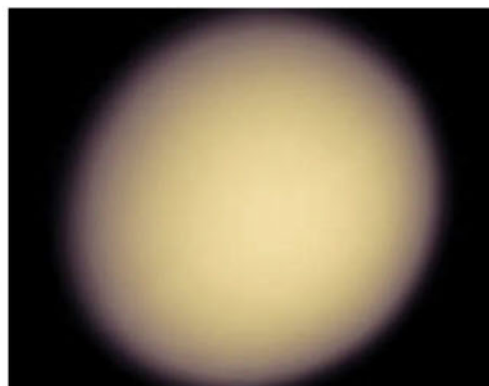
Date: 23 July 2015
Phase: 14.5%
Constellation: Leo
Magnitude: -4.07
Minimum optical aid: Unaided eye

closer in than us, would we see the effect. That sounded the death knell for Ptolemy's geocentric idea that Earth is at the centre of the Solar System.

If you mimic Galileo's observations of Venus via a telescope there are some things to keep in mind. First and perhaps counter-intuitively, it doesn't always pay to observe Venus when it is dark. The planet isn't far from the ground by the time the Sun is setting, even at greatest elongation. That means you are looking at the planet through deeper layers of haze and gas in the atmosphere, resulting in Venus significantly shimmering or wobbling in the eyepiece. Second, due to its extreme brightness, under magnification it can be dazzlingly bright. Both can be avoided by observing Venus during daylight hours - a particularly safe thing to do at greatest elongation as Venus is far from the Sun in the sky.

Your other angle of attack is to use telescopic filters. Yellow, blue or violet filters can help knock down some of the planet's brightness and under great viewing conditions may even allow you to pick out faint surface features in the clouds. Alternatively, red and orange filters help dial down some of the sky's background brightness, which is especially good

Venus's phases are evident when observing it, as this image taken by astrophotographer James Parker shows



for observing Venus during the day against the blue light of the sky.

However you choose to view Venus, either with the unaided eye, binoculars or a telescope, it is one of the easiest targets to find in the sky. It has played a role in the development of astronomy, from the cuneiform tablets of ancient Iraq to Galileo's game-changing observations in the 17th century.

Venus's conjunctions for your diary

Conjunction between Venus and Jupiter

Date: 30 June 2015

Time: Evening (the later the better)

Observer's notes:

The two brightest planets in the sky will appear to nestle close to each other on the border of the constellations Leo and Cancer, getting to within less than half a degree of each other.

Conjunction between Venus, Jupiter, crescent Moon and Regulus

Date: 18 July 2015

Time: Evening (the earlier the better)

Observer's notes:

These four objects will all be within five degrees of each other on this evening, forming an obvious quadrilateral that spans both Leo and Sextans.



Citizen space science

You can get in on the action of real science and help make ground-breaking discoveries with our pick of the top projects on the web

So much data, so little time. That's the usual problem professional astronomers find themselves faced with. This is where citizen science comes in. You can help with projects so that experts don't have to spend most of their time working through reams of data. This data is collected by spacecraft, as well as the ground-based telescopes of past and present, giving you the opportunity to discover something entirely new. Gone are the days where you needed a PhD in space science to get a good look around the universe. What's more, all you need is a computer and an internet connection to get in on the action of real science today.

Citizen science allows you to get up close and personal with the fiery surface of the Sun, or

target asteroids whizzing through the Solar System. If you're looking to leave the solar neighbourhood, you can head into deep space to get a closer look at the supermassive black holes found at the centres of galaxies, or even discover an alien world around a distant star.

If you have ever been out under the stars with a telescope, or even without one, you are potentially contributing to citizen science. If you were to chance upon a supernova in the process of exploding, or spot a brand new comet or near-Earth asteroid, then your next step would be to report it to an astronomical organisation. If your new discovery is confirmed, you will have contributed significantly to the bigger picture of our universe.

Swapping a telescope for a computer opens up even more possibilities to discover something new in the cosmos, with just a few clicks leading the public to their own unique discoveries.

Our guide reveals the deluge of citizen projects out there that wield an enormous amount of space data, some of which could crack the baffling mysteries that pervade the cosmos.

It's so easy to get involved and make a contribution to science

Planet Four

www.planetfour.org

Mission statement

With landers, rovers and orbiters having made their way to the Red Planet to get a closer look, you would be forgiven for thinking that we already have everything we need to keep an eye on Mars. However, human eyes are favoured over robotic ones in this case, with experts calling on citizen scientists to pore over images returned by the Mars Reconnaissance Orbiter (MRO). In a similar vein to Moon Zoo, Planet Four requires you to highlight any odd features that pepper the Martian landscape and have escaped the notice of professional astronomers, orbiters, landers and rovers.

Solar Stormwatch

www.solarstormwatch.com

Mission statement

It's no secret that our Sun has plenty happening on its surface, which often results in solar flares and coronal mass ejections being thrown angrily from its limb. Our Earth responds to it by producing colourful light shows called auroras, which can be witnessed at the planet's poles. Outside of our planet's confines it's a different story, as satellite communications and astronauts can become seriously affected by it.

Solar Stormwatch gives you the tools you need to give an early warning sign to astronauts when dangerous solar radiation could be headed their way. Not only that, but you could make an important discovery about our Sun.



Touring the Solar System

You recognise it as home, but it's still possible to uncover something new.

Moon Zoo

www.moonzoo.org

Mission statement

Moon Zoo is part of the larger Zooniverse project, which kick-started with the galaxy classification effort, Galaxy Zoo. Using images returned by the Lunar Reconnaissance Orbiter (LRO), Moon Zoo gives you the chance to observe the lunar surface in unprecedented detail. Your task is to identify any noticeable features that could interest scientists, whether it's a boulder, crater or some other unusual feature protruding out of the soil. When you have finished with each image, your hard work is saved to the Moon Zoo database ready for planetary scientists to look over and analyse.

Asteroid Zoo

www.asteroidzoo.org

Mission statement

The Zooniverse project and Planetary Resources have teamed up to bring citizen science project Asteroid Zoo to the public, giving you the chance to find undiscovered asteroids. You could potentially discover a near-Earth asteroid on a collision course with our planet. That's not all though, any chunks of space rock that you do find could be the basis for future asteroid mining or sample collection expeditions that will help us to get a better idea of how our Solar System formed.

Cities at Night

www.citiesatnight.org

Mission statement

Light pollution is the astronomer's worst enemy, since it washes out the night sky gems that they like to observe. Because computers struggle to distinguish between artificial lights, the Moon and stars, human eyes are needed to analyse the light pollution on our planet from images taken by International Space Station astronauts.

With over 1 million images to sort through, you could help to stop wasted energy and preserve darker skies across the world.

Sunspotter

www.sunspotter.org

Mission statement

There are currently over 16,000 volunteers sorting through images in order to help organise sunspots (the cooler regions of the Sun's surface) and get a better idea of how our star's monstrous magnetic activity affects us here on Earth.

Part of the Zooniverse project, Sunspotter is an easy project to get involved with. Your analysis of images returned by the Solar and Heliospheric Observatory (SOHO) would play a major part in understanding our star.



Probing deep space

Leave our solar neighbourhood for the chance to sniff out new planets and black holes

Agent Exoplanet lcogt.net/agentexoplanet

Mission statement

Agent Exoplanet puts you in the shoes of professional astronomers that measure dips in a star's brightness as an exoplanet glides across its surface. It's from here that we're able to get a great deal of information about an alien world, such as how long it takes for the planet to orbit its star along with characteristics such as its mass and how big it is.

Your mission is to trawl through the exoplanet data gathered by the Las Cumbres Observatory Global Telescope Network's integrated set of robotic telescopes in Hawaii, Australia, Chile, South Africa and Texas.

Galaxy Zoo 4 www.galaxyzoo.org

Mission statement

By combining new images from the Sloan Digital Sky Survey, the United Kingdom Infrared Telescope in Hawaii and the most distant images from the Hubble Space Telescope, Galaxy Zoo 4 requires you to classify galactic structures according to their shapes. There's always the opportunity to find galaxies that are peculiar enough to be flagged up to scientists.

The idea is that by putting the galaxies that you classify into categories, we're then able to figure out just how they formed and what their stories can tell us about the past, present and future of the universe as a whole.

Radio Galaxy Zoo radio.galaxyzoo.org

Mission statement

The aim of the game with Radio Galaxy Zoo is to find black holes at the centre of galaxies. Sure, it's difficult to find them by trying to locate them in optical wavebands, but that's where looking in radio wavelengths comes in.

It's no secret that these high-gravity objects like to eat. And by gorging on gas and dust they give off jets that are tuned to a radio frequency. Thanks to the likes of the Australia Telescope Compact Array, we can locate the very jets that give away a black hole's whereabouts.

Planet Hunters www.planethunters.org

Mission statement

Perhaps one of the most exciting space objects to discover is an alien world. Computers usually sift through data returned by the likes of the crippled exoplanet hunter, Kepler, but it is still possible that these machines can miss alien world candidates.

The human ability to be able to recognise patterns is where you could have an advantage over machines, giving you the opportunity to find an exoplanet that could possibly be Earth 2.0. All you have to do is flag up any dips in brightness in what are known as light curves hidden in the Kepler Space Telescope's data.

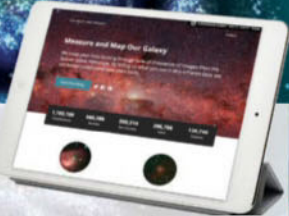
The Milky Way Project

www.milkywayproject.org

Mission statement

We can get a bit more of an understanding of galaxies like the one we call home by looking more closely at the many different types of stars and planets that exist within it. However, despite living so close to all of the action, there is still much that we don't know about the Milky Way.

Just like Planet Four and Moon Zoo, the user classifies objects in images of our galaxy, pointing out any star clusters or galaxies beyond the Milky Way's confines as well as bubbles. Our galaxy is massive, so there is a real possibility that you will find something truly amazing in data returned by the Spitzer Space Telescope.



Disk Detective

www.diskdetective.org

Mission statement

Distant worlds don't just appear out of nowhere. Planets are made from dusty debris discs circling a star. Disk Detective sorts out the stars that have discs of debris around them from those that don't, thanks to information collected by the WISE spacecraft.

Seeing as it's quite easy for computer programs to confuse these discs with other objects that litter the universe, you could be the first to find a dusty disc in the process of making its very own baby planets.



SETI@Home

setiathome.ssl.berkeley.edu

Mission statement

We know for certain that exoplanets exist beyond our Solar System, but what about alien life that's intelligent enough to communicate with us? SETI, which is short for the Search for Extraterrestrial Intelligence, hunts for such life, but they can't do it alone. SETI needs your help.

If you want to get involved in citizen science but don't have the time to analyse data, then SETI@Home could be the project for you. All you need to do to be part of it is to run the downloadable software, known as BOINC. This then allows your computer to work with other internet-connected computers in downloading and analysing radio telescope data from the Arecibo radio observatory in Puerto Rico – the biggest radio dish in the world.



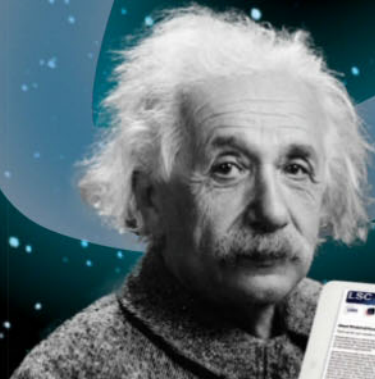
Einstein@Home

www.einsteinathome.org

Mission statement

Just like SETI@Home, Einstein@Home uses your computer's idle time along with the BOINC software to seek out weak signals from spinning neutron stars known as pulsars. This is in the hope of grabbing the first direct detection of elusive gravitational waves, which are the ripples in the fabric of space-time.

The project uses data from the LIGO gravitational wave detectors in Louisiana and Washington, the Arecibo radio telescope in Puerto Rico and the space-based Fermi Gamma-ray Space Telescope.





Spectroscopy for beginners

Learn how to analyse starlight to uncover hidden gems in the universe

Getting started

1 Attaching filter to camera

You're going to want a camera to record your spectra. Then attach a spectroscopic filter, like the Star Analyser 100, which will split the light into its constituent colours.

2 Attaching camera to telescope or tripod

You don't necessarily need a telescope, you could attach your filter to a DSLR camera. If so, mount it on a tripod. If you are using a telescope, attach your camera to it.

3 Find your target

Having decided on your intended target, now it is time to line up your telescope (or camera on a tripod) with the object you'd like to take a spectrum of.

4 Capture the spectrum

If using a webcam, capture some videos (at least 30 seconds) and record to your computer. With DSLR cameras, play with the exposure for the best results.

5 Analyse the data

Use computer software such as RSpec to turn your raw data into a fully fledged spectrum, from which you can draw scientific conclusions.

Astronomy is a pretty unique scientific pursuit. Unlike biology or geology, you can't just go out in the field, readily collect samples and bring them back to the lab. Granted, a few lunar samples have been returned from the Moon and a few grains of asteroid dust and solar wind have been brought back to Earth, but these are the exceptions and not the rule. You certainly can't get your hands on a star. So astronomers have to be clever instead, using what is often the only tool at their disposal - light.

Light is the universe's postal service, delivering information across the cosmos about the nature of its source. One of the major ways astronomers are able to read these messages is to use the technique of spectroscopy, effectively splitting the light up into its colour spectrum using a fancy version of a prism. For example, if you do this with the Sun's light, at first you get what you would expect: a spectrum containing the seven colours of the rainbow

from red to indigo and violet. Yet if you look closer you will notice that throughout the spectrum many of the colours are missing, replaced instead by dark black bands. These are known as absorption lines, created when different chemical elements in the Sun have absorbed those specific colours of light and prevented them from reaching Earth. So, in effect, these absorption lines are like a fingerprint or barcode, betraying the chemical contents of the Sun even though we cannot get anywhere near it. In fact, helium was first discovered in the Sun before it was discovered on Earth, hence its name 'helios', which is Greek for the Sun.

However, spectroscopy can be used for far more than determining chemical composition. If the source of the light is moving away from us then the absorption lines will appear to be shifted toward the red end of the spectrum (redshift). In contrast, a light source that's moving toward us will have its lines closer to the blue end (blueshift). This was exactly the same technique used by Edwin Hubble when he charted the recession speed of distant galaxies and realised the universe was expanding.

But spectroscopy isn't just restricted to professional astronomers and you too can get in on the act. One of the simplest ways to do so is to use an old CD or DVD and a cereal box. A quick search online will give you the full instructions. The American Physical Society have even developed an app called SpectraSnapp that will allow you to turn your smartphone into a spectroscope. If you have a telescope, you can also buy special spectroscopic filters that will allow you to see the spectra of individual objects.

Once you're comfortable with your setup, a good project with spectroscopy is to try and work out the rotation rates of Jupiter or Saturn. The spectral lines will be redshifted on the limb of the planet moving away from us, whereas the lines on the other limb will be blueshifted. The faster the planet is spinning, the more the lines will move. ■



Top 5 targets

Now that you're all set up, it's time to start discovering the best spectroscopic targets in the sky

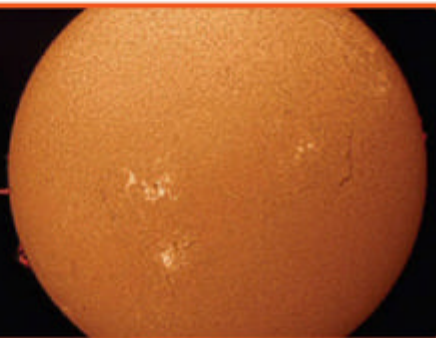
Sun

Object: Star

Constellation: N/A

Observer's notes:

As with all solar observation you have to be very careful not to damage your eyes – do not look directly at the Sun. A solar spectrum will show the usual rainbow colours with the Fraunhofer lines, which are the dark bands in spectrum.



Jupiter

Object: Planet

Constellation: Cancer and Leo during 2015

Observer's notes:

Like Venus, Jupiter is an easy target for beginners. The dominant features in its spectrum are three separate and broad regions of absorption, which are caused by methane high in Jupiter's cloud decks. You could also try and calculate the planet's rotation.



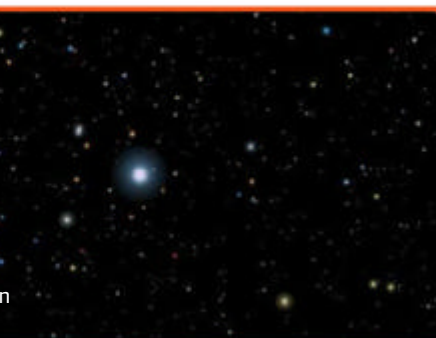
Vega

Object: Star

Constellation: Lyra

Observer's notes:

Vega is one of the brightest stars in the sky. Its spectrum will show three particularly clear absorption lines, two in the blue part of the spectrum and one in the red. These are known as the hydrogen alpha, hydrogen beta and hydrogen gamma lines.



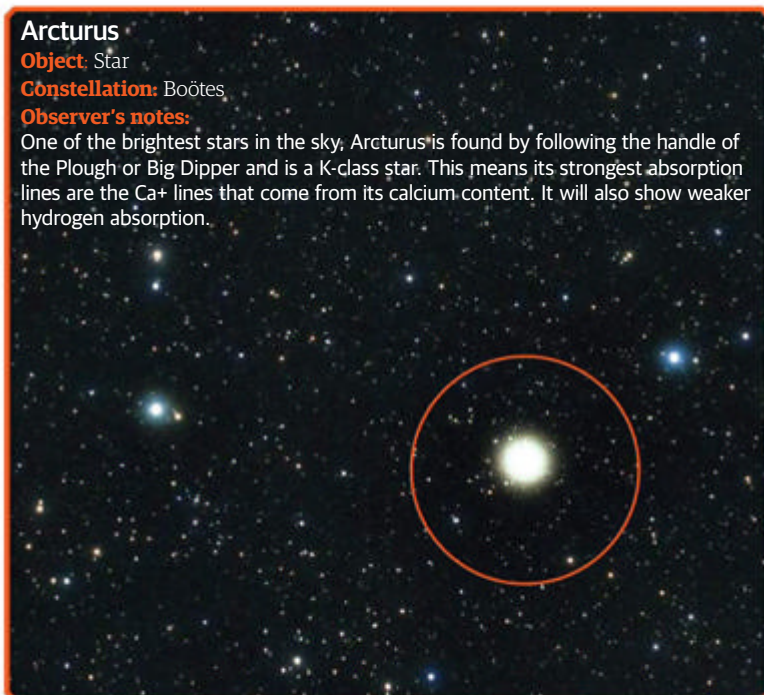
Arcturus

Object: Star

Constellation: Boötes

Observer's notes:

One of the brightest stars in the sky, Arcturus is found by following the handle of the Plough or Big Dipper and is a K-class star. This means its strongest absorption lines are the Ca+ lines that come from its calcium content. It will also show weaker hydrogen absorption.



Venus

Object: Planet

Constellation: Gemini, Cancer and Leo during 2015

Observer's notes:

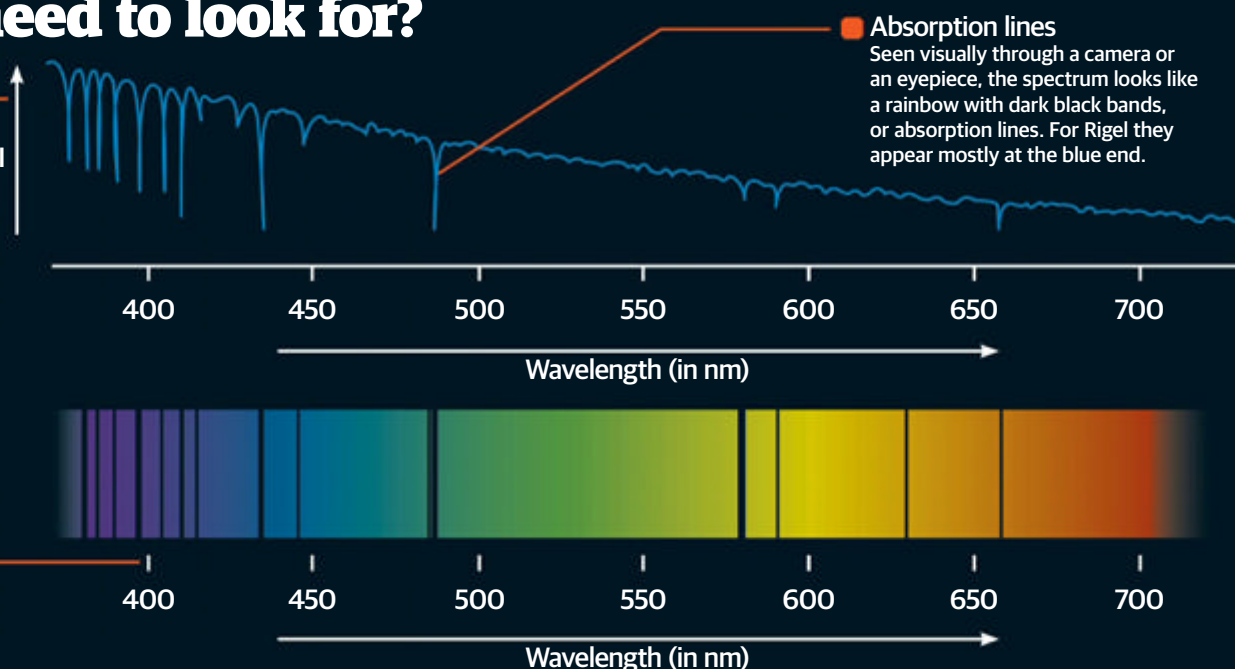
Venus is an easy spectroscopic target because it is so bright. If you compare the spectra of Venus and the Sun they will look reasonably similar as Venus reflects so much sunlight. The main difference will be its additional absorption lines.



What do I need to look for?

Blue star
A star's surface temperature dictates its colour. Rigel, in the constellation of Orion, is a hot blue star that can be seen from its spectrum because the light is most intense at the blue end.

Visualising it graphically
If you use computer software to turn your spectrum into a graph, you can see how much the light drops in that part of the spectrum, ie the strength of the absorption.





What's in the sky?

The skies of late spring are filled with deep-sky delights for observers as we look out into the depths of space

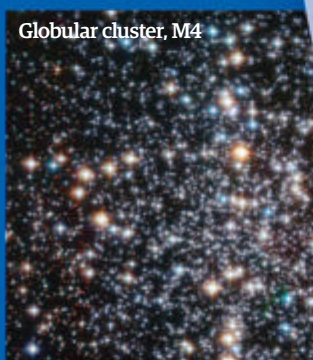
Using the sky chart



Please note that this chart is intended for midnight mid-month and set for 45° latitude north or south respectively.

- 01 Hold the chart above your head with the bottom of the page in front of you.
- 02 Face south and notice that north on the chart is behind you.
- 03 The constellations on the chart should now match what you see in the sky.

Globular cluster, M4



Globular cluster, M4

Viewable time: For roughly an hour or two either side of midnight

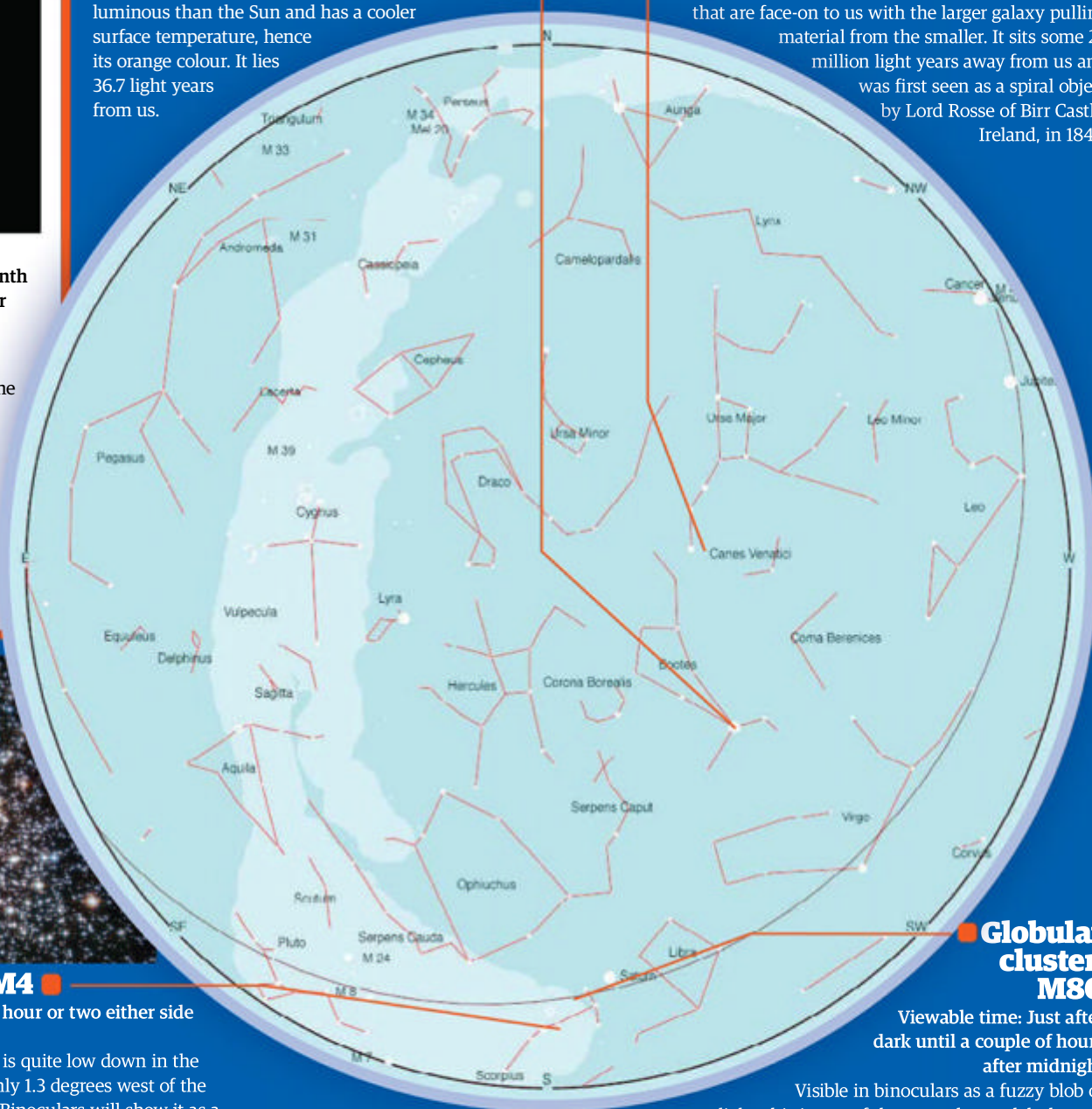
This lovely globular star cluster is quite low down in the south but easy to spot as it is only 1.3 degrees west of the bright star Antares in Scorpius. Binoculars will show it as a fuzzy blob of light and a small telescope will start to pick out some of the outer stars of the cluster. At a distance of around 7,200 light years, it is one of the closest globular clusters to us and is 12.2 billion years old.

Star, Arcturus

Viewable time: All through the hours of darkness
You can't miss the bright star Arcturus on a summer's evening. It is the brightest star in the north celestial hemisphere and the fourth-brightest star in the entire night sky. It is an orange giant star 110-times more luminous than the Sun and has a cooler surface temperature, hence its orange colour. It lies 36.7 light years from us.

M51, The Whirlpool galaxy

Viewable time: All through the hours of darkness
The Whirlpool galaxy is not very easy to find due to its fairly low surface brightness. It is probably the most famous object in the night sky after the Andromeda galaxy. It is in fact two gravitationally bound galaxies that are face-on to us with the larger galaxy pulling material from the smaller. It sits some 23 million light years away from us and was first seen as a spiral object by Lord Rosse of Birr Castle, Ireland, in 1845.



Northern hemisphere

Globular cluster, M80

Viewable time: Just after dark until a couple of hours after midnight

Visible in binoculars as a fuzzy blob of light, this is one of the more dense globular star clusters which orbit our galaxy. Many of the outer stars can be resolved in a small telescope, so this lovely globular cluster is well worth a visit. It lies at an estimated distance of 32,600 light years from Earth.

■ Globular cluster, NGC 5986

Viewable time: All through the hours of darkness
This globular cluster in the constellation of Lupus contains stars as old as 12.6 billion years! That makes them some of the very oldest stars in the known universe. Although you'll need a telescope to see this object well, binoculars will show it as a small misty patch with a granular look. A telescope will start to resolve the many hundreds of thousands of stars in this cluster. It lies around 33,900 light years away from us.

Southern hemisphere

■ Open star cluster, NGC 5316

Viewable time: All through the hours of darkness
NGC 5316 is an attractive star cluster situated in the band of the Milky Way, stretching across the sky from south-west to north-east during the southern hemisphere's winter months. It nestles in the constellation of Centaurus near the bright star Hadar, or beta Centauri. Its 20 or so bright stars show up well in binoculars and small telescopes, with larger scopes starting to resolve many of the fainter stars in the group. The cluster is around 3,960 light years away from us.



■ Open star cluster, NGC 6193

Viewable time: All through the hours of darkness
You can find this star cluster in the constellation of Ara, close to the border with the constellation of Norma. It is associated with the emission nebula NGC 6188, which is a star forming nebula. The cluster is visible to the naked eye and can easily be seen through binoculars, but the nebula only shows up in long exposure imaging. It occupies a region of space around 600 light years across and sits some 4,000 light years away.

■ Globular cluster, NGC 4833

Viewable time: All through the hours of darkness
Abbe Lacaille discovered this globular star cluster in 1752 on his trip to South Africa. It was subsequently both observed and catalogued by James Dunlop and Sir John Herschel. It was the latter whose telescope could resolve many of the individual stars in the group. It lies 21,200 light years from us in the constellation of Musca and is thought to be one of the older globular clusters at around of 12.5 billion years of age.

Globular cluster, NGC 5986

Globular cluster, NGC 4833



Me & My Telescope

Send your astronomy photos and pictures of you with your telescope to **photos@spaceanswers.com** and we'll showcase them every issue

Sarah & Simon Fisher

Bromsgrove, Worcestershire
Telescope: Sky-Watcher
Skymax 127

"We were absolutely thrilled to have captured the partial solar eclipse on 20 March. It was fabulous to observe and photograph using solar filters, our 127mm Maksutov and a Canon 600D camera.

"The night sky has spoilt us recently as we managed to capture a conjunction between Venus, Mars and the Moon, as well as Jupiter and its Galilean moons, which were all on one side of the gas giant in February."



Gas giant Jupiter with
Io, Europa, Callisto
and Ganymede



A montage of the
partial solar eclipse
on 20 March





Katherine Ormerod

Chorley, Lancashire

Telescope: Celestron NexStar 5SE

"I am 15 years old and began to have an interest in space around two years ago. It wasn't until a few months ago that I developed a strong interest in astronomy."



"Both in and out of school, I have always been interested in science, particularly physics. My passion has led me to buy a telescope with the aim of viewing the Solar System and the Moon. I find the lunar surface very interesting because of the incredible detail that you can see with a low magnification. If I can't see the Moon, then Jupiter is also one of my favourite objects to view."

The International Space Station travelling through the night sky



Another shot of the ISS, taken with a telescope and CCD camera

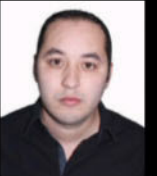


Fayçal Demri

Algiers, Algeria

Telescope: Celestron CGEM DX 1100

"I began my hobby in astrophotography two years ago with a 5" Maksutov-Cassegrain telescope and a webcam. My first images were not brilliant, but with some practice and determination I was able to take high-resolution images of bright objects from light-polluted cities. "To image the International Space Station I use an 11" Schmidt-Cassegrain telescope and a CCD camera. The ISS moves fast, so it's important to focus in advance."



Send your photos to...  @spaceanswers  photos@spaceanswers.com

Stargazing stories

Email the story of how you got into astronomy to **photos@spaceanswers.com** for a chance to feature in **All About Space**

David Bood



Location: Bridlington, East Yorkshire

Twitter: @DavesAstronomy

Info: Astronomer for five years

Current rig

Telescope: Sky-Watcher 130

Mount: EQ2

Other: Nikon D3200 camera, 70-300mm lens

"I got into astronomy by accident. However, before I began my hobby, I did gain a general interest in the cosmos through watching documentaries on the Discovery Channel as well as watching the show *Meteorite Men* with Geoff Notkin and Steve Arnold.

"It was my wife who suggested that I needed a hobby and encouraged me to get fully involved in astronomy, so she bought me my first telescope - a Celestron AstroMaster 130EQ. Later on a friend of mine, who is a member of the Scarborough and Ryedale Astronomical Society, invited me along to one of the society's events. The president, John Harper, was giving a talk at the time and he drew me in and captivated me. After the talk we went out to view the night sky, this was when I first observed Saturn and it blew my mind.

"One of my favourite sites to stargaze is the Dalby Forest in North Yorkshire, which has a fantastic dark sky. Scarborough and Ryedale Astronomical Society hold public events there and I can fully make use of a beautifully clear sky that is untouched by light pollution. My other favourite place is in my back garden and I am lucky enough to be able to observe from here with some spectacular results. Since getting into the hobby I have become an avid blogger and this has led to interviews with many leading people in astronomy, including Geoff Notkin as well as contact with a Rosetta spacecraft scientist, NASA's Claudia Alexander. I now find myself doing a lot of courses and studying the science behind the cosmos. Recently I have taken up photographing the night sky, although this is a work in progress!" ●

David's top three tips

1. Familiarise yourself with the night sky

There are many apps and charts out there to help you learn your way around. Stellarium is one of my favourites.

2. Join a club or local group

This gives you the opportunity to learn from other astronomers, especially when it comes to getting advice on which telescope to buy.

3. Do your research

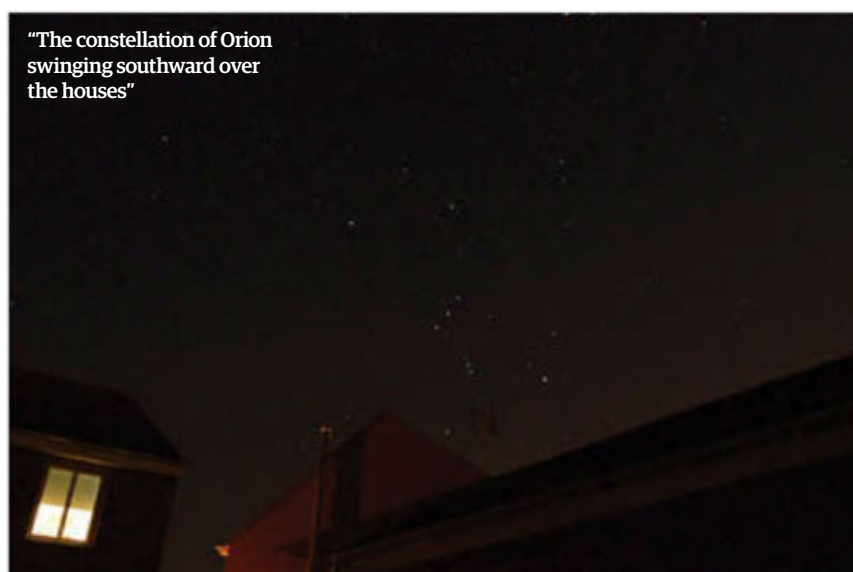
You should always ensure that you get the best equipment you can afford. Get advice and read as much as you can on telescopes before purchasing one.



"An image of the Moon taken with a Nikon D3200 mounted to a Sky-Watcher 130"



"I shot Orion's Belt while playing with the camera settings"



"The constellation of Orion swinging southward over the houses"

Send your stories and photos to... [@spaceanswers](https://twitter.com/spaceanswers) [@ photos@spaceanswers.com](mailto:photos@spaceanswers.com)

"The greatest extent, around 90 per cent solar eclipse coverage, as seen from East Yorkshire on 20 March"

STARGAZER

Stargazing stories



"My effort at imaging the Orion nebula in the constellation of Orion"

Steve Wright



Location: Burstwick, East Yorkshire

Twitter: @astrostevp

Info: Astronomer for ten years

Current rig

Telescope: Vixen ED81S, Sky-Watcher Explorer 150P, Sky-Watcher Evostar 90

Mount: HEQ5, EQ3-2, AZ4

Other: Canon 600D camera

"Although I have been interested in astronomy for as long as I can remember, my enthusiasm for this hobby began in earnest during my time as a physics student at the University of York.

"It was at this time that I joined the university's astronomical society and got my first taste of using some high quality telescopes at their observatory. The moment I was hooked for life was the first time I saw Saturn through the eyepiece - an experience that many astronomers can identify with. That night, after looking through the eyepiece at the ringed planet, I was hurried along a queue so that other members of the society would get their turn. I hastily snapped an afocal

shot with my brand new mobile phone and had taken my very first astrophotography image.

"Fast forward a few years and my observing is now done from my home in the east of Yorkshire, living just far enough away from Hull's city glow to be able to enjoy my hobby with my modest equipment sat atop a homemade pier.

"As well as all of the usual favourites to observe, one of the best is our nearest and dearest star, the Sun. My first experience of solar observation was the 1999 total solar eclipse, which I viewed from Amsterdam. I was over the Moon to be able to witness the 20 March partial eclipse, but this time armed with my own equipment." ●

"I was hooked for life the first time I saw Saturn through the eyepiece"

Steve's top three tips

1. Try out binoculars

Some of my best sessions have been when I've ditched the telescopes in favour of a pair of binoculars. They can be relatively cheap and are great to just grab and go.

2. Get a decent-quality mount

Buy the best mount you can afford. A lesser telescope on a more solid mount will outperform the better instrument on a wobbly one.

3. Portability is important

If you plan to transport your instrument for observations, think twice about a heavy telescope. If it is too heavy you won't be able to use it.

"An eight-second exposure of the ISS, the moon and Jupiter"



Celestron NexStar 127 SLT

A small telescope that packs a punch, the NexStar 127 SLT is an ideal companion for observations of the Solar System

Telescope advice

Cost: £505 / \$549.95

From: David Hinds Ltd

Type: Maksutov-Cassegrain

Aperture: 5"

Focal length: 59"

Best for...



Beginners



Medium budgets



Planetary viewing



Lunar viewing



Bright deep-sky objects



Basic astrophotography

If you're looking for an affordable entry-level telescope for planetary viewing that will take a few years to outgrow, then the NexStar 127 SLT could be the instrument for you. At just £505 (\$549.95), we think that this Maksutov-Cassegrain is a worthy contender for those wishing to upgrade on their basic scope.

When unboxing the 127 SLT, the telescope's high quality was immediately noticeable and setting it up was really easy. If this is your first time using a computerised scope and you're concerned about putting it together then there's no need to worry - the procedure in getting the GoTo facility up and running is fairly straightforward, meaning that the 127 SLT is fully-functional in a matter of minutes. Celestron provides a step-by-step guide along with software to help you with alignment and we do recommend that you have a very good idea of how the SkyAlign software works before heading outside for an evening, as reading instructions in the dark may prove to be difficult.

The mount includes a spirit level and it's important to make use of this to ensure that the GoTo system is able to achieve optimum performance. Completely set up, the 127 SLT is extremely portable, making it ideal for astronomers who like to switch between observing in their garden to travelling to darker sites.

We chose three bright stars that were sufficiently separated for alignment, with the telescope responding very well to our choice and it wasn't long before we began touring the night sky. The GoTo system responded very well during our review and will certainly take the pain out of locating objects.

Unfortunately, this Maksutov-Cassegrain does have a few downsides. The 127 SLT is quite top-heavy and while it wasn't on the brink of falling over, we do recommend investing in a tripod that's able to hold the mount and tube much more comfortably. Additionally, the tripod vibrates while the GoTo's motors are in motion, even with the slightest touch.

"Observing the lunar surface was breathtaking with this telescope"

Two plössl eyepieces are supplied, a 9mm and 25mm to provide magnifications of 167x and 60x



As a result, we needed to stop and start focusing for a steady view since the target bounced around the field of view if we tried to look through the eyepiece and bring the object into focus simultaneously. Another problem we found is that the telescope is quite demanding of the eight AA batteries that it requires. It's a given that they won't last for very long in cold conditions and the supplied batteries were drained in less than a couple of hours of observation. If you're looking at using this power solution, we recommend investing in good alkaline batteries and avoiding the rechargeable ones due to their lower voltage. We do think it's wise to get hold of a 12V DC power socket for observing, something the telescope isn't supplied with.

During our review, we took advantage of a waning gibbous Moon, using the supplied 9mm and 25mm Plössl eyepieces, which provided magnifications of 167x and 60x.

The telescope is powerful but drains its eight AA batteries quickly

The 127 SLT's optical system is very good for touring the Solar System



Observing the lunar surface was breathtaking with this telescope, with craters, rilles and lunar mares being highly resolved and extremely clear. We ran along the Moon's terminator, taking in exquisite views of the rugged surface where bright meets dark. The craters Catharina, Aristoteles and Cyrillus were particularly stunning, with shadows falling across them beautifully and truly making them pop. Heading over to the brighter craters of Tycho, Longomontanus and Clavius, the 127 SLT's optical system once again produced beautiful, clear and crisp results.

The telescope's database contains around 4,000 objects. Sadly though, a good proportion of these are faint deep-sky objects that the 127 SLT's optical system just isn't capable of viewing due to its long focal length and small aperture. You will be able to make out a smudge of light when observing galaxies, but this telescope is best used for Solar System objects

and the brighter deep-sky targets. We were able to resolve Jupiter's cloud bands and cleanly separate several pairs of double stars with ease due to the good seeing conditions. Sights are clear across an excellent proportion of the field of view and as expected with catadioptric telescopes, any colour fringing is completely eliminated. We certainly cannot fault the telescope's brilliant optics.

Since the telescope makes use of an alt-azimuth single arm mount, it's difficult to use it for serious astrophotography. However, we were able to get fair images using a DSLR camera and short exposures - something that beginners will no doubt be pleased with.

Overall, we are pleased with the performance of the NexStar 127 SLT and its versatility in being able to be accessorised further. If you're an astronomer interested in planetary or lunar work, then this telescope is a great purchase with stunning optics. ●

The tripod is made of sturdy stainless steel, but does shake when the GoTo motors are in operation and even with the slightest touch of the focussing knob



The fork arm will allow for some basic astrophotography



Space television series

When it came to watching the universe through a television, which show got our vote?

Cosmos: A Spacetime Odyssey

Cost: £16.25 / \$59.98

From: Amazon

Cosmos with Neil deGrasse Tyson is the modern sequel to Carl Sagan's *Cosmos* series from 1980. Tyson was a student of Carl Sagan and is a well known astronomer and science communicator, so who better to fill Sagan's shoes? The new *Cosmos* takes the same approach as the original series, as we follow Tyson on a personal journey across time and space, the origins of life and the universe. Neil deGrasse Tyson is an excellent presenter but we did find that some of the episodes could be

a bit slow because not everything was about space and astronomy. As an example, Tyson talks a great deal about evolution, which is very fascinating, but may put some viewers off if they are looking for a purely space-centric experience.

The special effects are wonderful, as is the soundtrack and sometimes computer graphics are replaced by clever cartoons, like in the original series. The original *Cosmos* inspired a whole generation of scientists and we're sure that this will do the same.

The Universe

Cost: £99.99 / \$129.99

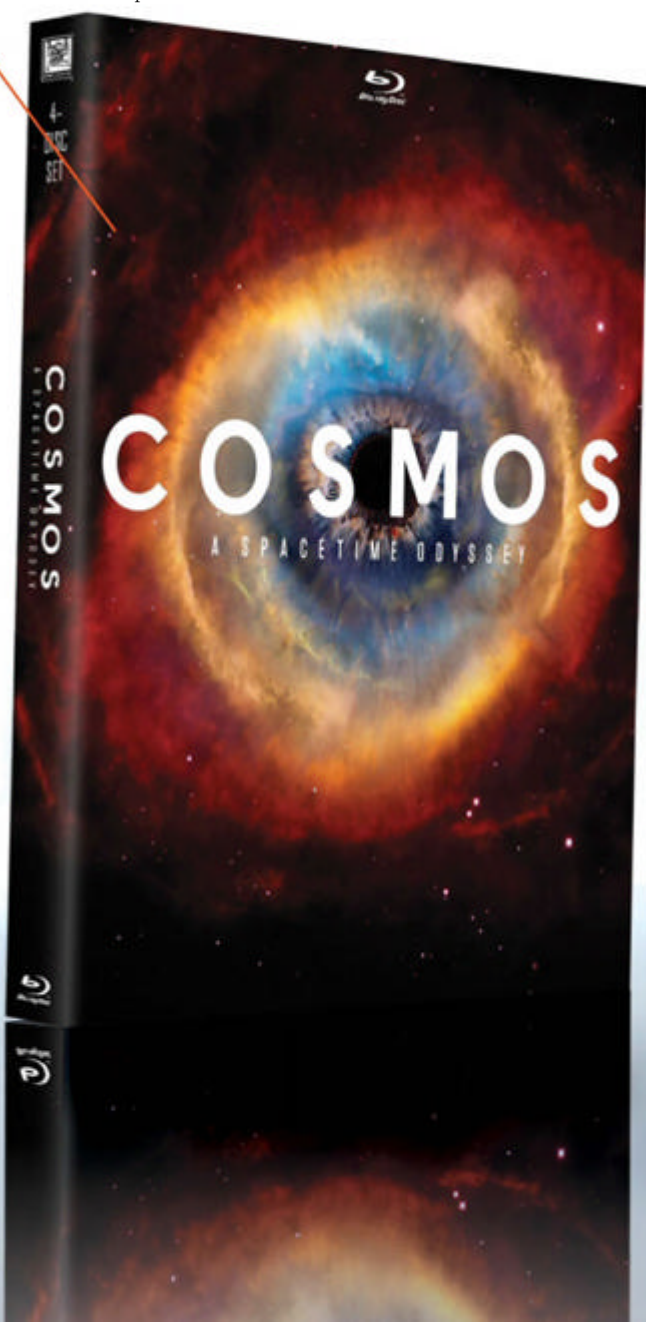
From: Amazon

The Universe is an American television series, each season of which is available to buy separately, or you can get the first five seasons in this 'mega collection' box set. Each episode is about a different topic such as gamma-ray bursts, black holes or the planets and features CGI special effects.

Throughout the series, we meet lots of scientists and go on a tour of telescopes all over the world.

The Universe really is exciting to watch as it makes sure that each moment is packed with a whiz-bang fact, or some interesting snippet of information from a scientist. It's not

just talking heads, because we get to see where these astronomers work, something that adds a personal touch to the show. Sometimes the scientists use their hobbies, ranging from things such as playing music to belly dancing, to illustrate something about their research. This might seem a touch strange to some but it made hardcore space topics easier to relate to. The special effects are pretty good for television, but because it is an American series the episodes are all Americanised, so expect to meet lots of US astronomers but very few from other parts of the world.



Verdict

Winner: Tie

These two TV shows approach the topic of space from different angles. If you're looking for something that has a gentle pace and is thoughtful and considered, you may prefer to watch *Cosmos*. On the other hand, if you are excited by fast and colourful special effects permeated with bursts of information, then *The Universe* might be your preference. Overall both are brilliant series and will teach you a great deal about the universe.





Astronomy kit reviews

Stargazing gear, accessories, games and books for astronomers and space fans alike



1 Book *The Secret Life of Space*

Cost: £20 (approx \$32)

From: Aurum Press

If you thought that you knew the true history of how we came to understand so much about universe, there is a chance that you could be wrong. At least that's what *The Secret Life of Space* promises you before you even begin reading its pages.

As with many books that are written from a historical perspective, its authors Heather Couper and Nigel Henbest ensure an engaging and lively read, leading effortlessly from one page to the next. The prose is easy to follow and each historical myth is debunked neatly in its own chapter.

We have to admit, unless you've been misled somewhere along the line during your learning of the history of astronomy, you won't be too surprised by many of the revelations presented in *The Secret Life of Space*. However, we have to say that a couple of chapters in this book shocked us! So it's definitely worth a read. ■

2 Eyepiece and filter kit Celestron 1.25" eyepiece and filter kit (improved version)

Cost: £200 / \$159.95

From: David Hinds Ltd

Celestron's entire set of improved eyepieces and filters are of very good quality. The superior grade Plössl eyepieces are fully multi-coated for maximum contrast and resolution, while boasting a design that promises to last for many years.

Eyepieces of 6mm, 8mm, 13mm, 17mm and 32mm are supplied and are versatile enough to work with a selection of telescopes thanks to their 1.25" fitting. Upon plugging them into our in-house reflector, the multi-coated lenses truly provided great views of a selection of night sky targets. The 13mm eyepiece made poor seeing conditions bearable and this eyepiece, along with the 6mm and 8mm, provided good planetary views. The eye relief is also good and when we turned our attention to the Moon, we were also able to get the full benefit of the supplied Moon filter. ■

3 App Star Rover

Cost: £1.49 / \$1.99

From: iTunes & Google Play

Star Rover allows you to see the constellations and planets on any given night and from any given location in the world. The interface is beautifully designed, featuring a dark star-studded night sky that can be divided up into both day and night with the help of a grid.

While Star Rover has a lot going for it in terms of design, its functionality isn't so brilliant and you need a lot of patience to use it. For one, the sky on Star Rover has stars that have been accentuated. In reality, these stars are too faint to see clearly with the naked eye. If you're in an area with even the slightest of light pollution, you may find this astronomy app fairly useless. Not only that, but there is next to no instructions on how to use it, meaning that users and beginners to astronomy looking for night sky guidance, are going to find themselves struggling to find their desired targets and will be put off fairly quickly. ■

4 Filter wheel Skyris 5-position 1.25" filter wheel

Cost: £130 / \$119.95

From: David Hinds Ltd

If you're a user of a monochrome CCD, then you can probably identify with the frustrations of fiddling with filters in order to get your red, green and blue shots for a later composite of your favourite night sky object. The filter wheel is nothing short of a saviour, allowing you to pop five filters into it and flip from one to the other easily.

The design of the filter wheel is of top quality and features a quick release. We have to say, it was very effective when it came to plugging in filters from the Celestron eyepiece and filter kit (also reviewed this issue). For the price though, we do think that filters should be included in the package and it's certainly possible to pick one of these up with additional filters in a similar price range.

Nonetheless, if you already have filters, then we can highly recommend purchasing a filter wheel for an easy imaging session. ■

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AN OLIVON T800 SPOTTING SCOPE!

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Courtesy of Optical Hardware (www.opticalhardware.co.uk), we've got an Olivon T800 spotting scope for you to win this issue.

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cratered surface of our lunar companion, as well as bright planets and star clusters. The beauty of the Olivon T800 is that it is extremely versatile, with its 1.25" eyepiece fitting allowing it to double up as a perfect tool for nature watching and digiscoping.

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Abe Silverstein was heavily involved in human rights organisations, as well as the Boy Scouts of America



Abe Silverstein

The father of the Apollo programme

Born in 1908 in Terre Haute, Indiana, Abe Silverstein was a curious and clever boy who was fated to help lead the American space programme from birth to maturity. Determined and fascinated by the way machines work, he received a Bachelor of Science in Mechanical Engineering in 1929 and by 1934 he achieved a Master of Engineering from the Rose Polytechnic Institute.

Silverstein's early proficiency and aptitude for engineering did not go unnoticed. After graduating in 1929 he was quickly snatched up by the predecessor to NASA - NACA. Known as the National Advisory Committee for Aeronautics, the agency placed Silverstein at the Langley Research Center. Employed as an aerodynamicist, Silverstein worked tirelessly on designing the Altitude Wind Tunnel, which would later be built in what was then the Lewis laboratory and now the Glenn Research Centre in Cleveland, Ohio. Talented and ambitious, Silverstein rose through the ranks until he was in charge of the Full-Scale Wind Tunnel. Not just a space pioneer, while working at Langley his aerodynamic research led to increased high-speed performance for many of the US combat aircraft that would be used in World War II.

In 1943 Silverstein was transferred to the Lewis laboratory as chief of the wind tunnel and flight division. With unrivalled knowledge he was perfectly equipped to direct research concerning propulsion and aerodynamics in the wind tunnel. This monumental research would lead to vital improvements in engine reciprocation and early turbojet aircraft engines.

After World War II had ended, Silverstein's work continued in earnest and he played a central role in designing and constructing America's first supersonic propulsion wind tunnels. Thanks to Silverstein's pioneering vision, the work in the facility led to great developments toward modern-day supersonic aircraft. By 1949 he was responsible for all research conducted at Lewis and just three years later he was appointed associate director.

As such a central figure in NACA, it is no wonder that in 1958 Silverstein was called to the headquarters in Washington DC to help plan the programmes for a new space agency - the National Aeronautics and Space Administration, better known as NASA. In need of some reliable, talented and visionary leaders, Silverstein was appointed as the director of NASA's office of space flight programme later on that year.

At this point the US was very much in the heat of the space race against the Soviet Union and in this position Silverstein was responsible for programmes that led to both manned and unmanned spacecraft. Using his innovative spirit, he directed projects that led to the Project Mercury space flights and world famous Apollo missions, eventually putting a man on the Moon. Silverstein had an even more obvious and direct influence on the famous programmes as he is credited with naming both of them. When asked what prompted him to suggest the name 'Apollo' at a 1960 NASA brainstorming meeting he simply commented "No specific reason for it. It was just an attractive name."

In 1961 Silverstein returned to Cleveland to serve as director of the NASA Lewis Research Centre where he was a central part of the development of advanced space-power propulsion systems. This led to the creation of the Centaur rocket stage, which was used to launch spacecraft.

In 1969, after 40 years of government service, Silverstein retired from NASA. However, his significant contributions to the world famous space agency did not go unrecognised. Silverstein was honoured with an abundance of awards and honorary doctorates throughout his life, including the prestigious Guggenheim Medal. Silverstein passed away on 1 June 2001 at the age of 92 and in 2014 it was announced that he would receive his rightful place in the National Aviation Hall of Fame. ●

All About Space

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